NUREG-1549: Decision Methods for Dose Assessment to Comply With Radiological Criteria for License Termination

Abstract

This draft NUREG-series report describes a methodology for calculating doses to demonstrate compliance with the radiological criteria for decommissioning and license termination. The methodology is designed to allow each licensee the flexibility to optimize their decommissioning activities within the context of the License Termination rule. Note that although this document is divided into multiple sections to simplify the discussion for different situations, the underlying modeling process is a smooth continuum of options.

The simplest method for calculating dose, generic screening (see Chapter 3), uses models and default parameters that the NRC developed for compliance screening calculations [Kennedy and Strenge, 1992]. The generic models and default parameters are intended to estimate the upper range of the dose that an individual could receive and are expected to overestimate the dose for most sites. The purpose of generic screening is to allow the licensee a simple and cost-effective method to demonstrate compliance with NRC regulations using a minimum amount of site-specific information. Such a screening approach is based on reasonably conservative assumptions since it must provide a reasonable level of assurance and must be applicable to a wide range of licensees, radionuclides, and processes. As such, it is expected to be appropriate for NRC licensees who have relatively simple decommissioning situations. The calculated value under generic screening conditions is simply a marker used to demonstrate compliance and is not intended to be a realistic dose estimate.

Generic screening may not be appropriate for licensees who have complex mixtures of radionuclides, unusual or unique decommissioning situations, or where the use of very conservative assumptions would result in unwarranted costs or inefficient and illogical remediation requirements. Licensees who prefer to use site-specific information can use the same models as are used for generic screening, but must substitute site-specific values in place of some or all of the generic default parameters (see Chapters 4 and 5). The resulting dose estimates are expected to be more realistic and provide less of an over-estimate of dose than that provided by the generic screening approach. Site-specific screening utilizes additional site-specific data to support the modification or elimination of a particular scenario or pathway, or to demonstrate that a parameter or group of parameters can be better represented by site specific values. Alternative exposure scenarios may be appropriate based on site-specific factors that affect the likelihood and extent of potential future exposure to residual radioactivity. Guidance has been included in this document regarding sources of information available to licensees that can be used to support modification of parameter values.

Two other documents that provide background for this publication are available for viewing or reproduction in paper or diskette for a fee at NRC's Public Document Room, located at 2121 L Street, N.W., Lower Level, Washington, DC 20555-0001; Web address <http://www.nrc.gov/NRC/PDR/pdr1.htm>; Telephone: 1-800-397-4209, or locally, 202-634-3273. These background documents are titled "Review of Parameter Data for the NUREG/CR-5512 Building Occupancy Scenario and Probability Distributions for the DandD Parameter Analysis" and "Review of Parameter Data for the NUREG/CR-5512 Residential Farmer Scenario and Probability Distributions for the DandD Parameter Analysis."

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Foreword

The NRC has amended its regulations to establish residual radioactivity criteria for decommissioning of licensed nuclear facilities. This draft NUREG provides a method for demonstrating compliance with the dose criteria and ALARA provisions of the unrestricted and restricted use requirements in 10 CFR Subpart E, Sections 20.1402 and 20.1403. The methodology described in this draft NUREG was developed to provide a logical, consistent decision process that could be a useful tool to support licensee planning of decommissioning activities and NRC review of license termination requests. To support this process, this draft NUREG describes a decision methodology, or "framework," to support implementation of the dose assessment requirements in Subpart E.

The steps and decision points of the decision framework support assessment of the entire range of dose modeling options from which a licensee may choose, whether it involves using generic screening parameters, changing parameters, or modifying pathways or models.

It is expected that, as this approach is applied to decommissioning decision making, changes may need to be made to the models, scenarios, and/or parameters. Licensees are encouraged to carefully evaluate this approach and provide information to the NRC regarding the need for changes. Specifically, the distributions developed for the model parameters are expected to be modified to incorporate new information, and the current broad screening is expected to be further developed into multiple screens based on regional or license-type considerations. The results, approaches and methods described herein are provided for information only and should not be considered a substitute for NRC requirements.

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1.0 Introduction

1.1 Use of Decision-Making Framework for Complying with NRC Regulations on Radiological Criteria for License Termination

This NUREG contains an overall framework for dose assessment and decision making at sites where the licensee has decided to begin the decommissioning and license termination process. The framework can be used throughout the decommissioning and license termination process for sites ranging from the more simple sites to the most complex or contaminated sites. This document represents information for using the framework to step through the decommissioning and license termination process.

This framework is designed to assist the licensee, the NRC, and other stakeholders in making decommissioning decisions. By doing so, the process allows the licensee to coordinate its planning efforts with the NRC's input, to conduct dose assessments and site characterization activities that are directly related to regulatory decisions, to optimize cost decisions related to site characterization, remediation, and land-use restrictions, to integrate analyses for As Low As Is Reasonably Achievable (ALARA) requirements; and to elicit other stakeholders' input at crucial points. The framework also provides an approach for treating some of the uncertainty associated with contaminated sites.

1.2 Content of the NRC regulations on Radiological Criteria for License Termination

On July 21, 1997, the NRC published in the Federal Register (62 FR 39058) a final rule incorporating a new Subpart E into 10 CFR Part 20 that includes radiological criteria for license termination. Subpart E provides the regulatory basis for determining the extent to which lands and structures must be remediated before decommissioning of a site can be considered complete and the license terminated.

Subpart E of Part 20 includes requirements for unrestricted and restricted use of facilities after license termination in Sections 20.1402 and 20.1403, respectively. Subpart E also addresses public participation in the license termination process, the finality of license termination decisions, time periods for dose calculations, alternate dose criteria, and minimization of contamination.

The criteria for releasing a site for unrestricted or restricted use are listed here (and summarized in Table 1.1):

> <u>§ 20.1402 - Criteria for unrestricted use</u> - a site is considered acceptable for unrestricted use if the residual radioactivity that is distinguishable from background radiation results in a Total Effective Dose Equivalent (TEDE) to an average member of the critical group that does not exceed 25 mrem/yr, including that from groundwater sources of drinking water, and the residual radioactivity has been reduced to levels that are as low as is reasonably achievable (ALARA).
>
> <u>§ 20.1403 - Criteria for license termination under restricted conditions</u> - a site is considered acceptable for license termination under restricted conditions if:
>
> (a) A licensee can demonstrate that further reductions in residual radioactivity necessary to comply with the provisions of § 20.1402 would result in net public or

environmental harm or were not made because the residual levels associated with restricted conditions are ALARA;

(b) A licensee has made provisions for legally enforceable institutional controls that provide reasonable assurance that the TEDE from residual radioactivity distinguishable from background to the average member of the critical group will not exceed 25 mrem/yr;

(c) A licensee has provided sufficient financial assurance to enable an independent third party to assume and carry out responsibilities for any necessary control and maintenance of the site.

(d) A licensee has submitted a decommissioning plan or license termination plan specifying that the licensee intends to decommission by restricting use of the site and documenting how the advice of individuals and institutions in the community who may be affected by the decommissioning has been sought and incorporated into the plan.

Table 1.1 - Summary of 10 CFR Part 20 Subpart E

	Unrestricted Release	**Restricted Release**	
Dose Criterion	25 mrem TEDE per year peak annual dose to the average member of the critical group	25 mrem TEDE per year peak annual dose to the average member of the critical group while controls are in place	100 mrem or 500 mrem TEDE per year peak annual dose to the average member of the critical group upon failure of controls
Time Frame	1000 years	1000 years	1000 years
Other Requirements	ALARA	ALARA, financial assurance, public participation	ALARA, financial assurance, public participation

(e) Residual radioactivity at the site has been reduced so that if the institutional controls were no longer in effect, there is reasonable assurance that the TEDE from residual radioactivity distinguishable from background to the average member of the critical group is as low as is reasonably achievable and would not exceed either: (1) 100 mrem/yr; or (2) 500 mrem/yr provided the licensee: (a) demonstrates that further reductions in residual radioactivity necessary to comply with 100 mrem/y are not technically achievable, would be prohibitively expensive, or would result in net public or environmental harm; (b) makes provisions for durable institutional controls; and (c) provides sufficient financial assurance to enable an independent third party both to carry out periodic rechecks of the site every 5 years to assure that the institutional controls remain in place and to assume and carry out responsibilities for any necessary control and maintenance of those controls.

This NUREG provides a method for demonstrating compliance with the dose criteria and ALARA provisions of the unrestricted and restricted use requirements in Sections 20.1402 and 20.1403.

1.3 Summary of Dose Modeling Approach and Assumptions

The approach to dose modeling discussed in this document is designed to support a demonstration of compliance with the specific criteria in 10 CFR 20 Subpart E.

This methodology is based on the premise that screening dose assessments are performed with little site-specific information. Licensees using screening would comply with more restrictive criteria, but would do so based on a decision to not expend resources for a more realistic dose estimate, and would have high assurance that the criteria would be met. However, for licensees with more complex situations or who choose to perform more realistic analyses, the methodology ensures that as more site-specific information is incorporated, the uncertainty is reduced and the estimate of the resulting dose generally decreases. This provides assurance that obtaining additional site-specific information is worthwhile because it ensures that a more "realistic" dose assessment will not generally result in a dose higher than that estimated using screening.

During the development of this approach, models, scenarios, and parameters were defined in DandD which were expected to be "reasonably conservative". The models and scenarios were specifically defined such that they would not be "bounding" or unrealistic, while still generally overestimating rather than underestimating potential dose. The model parameters were also evaluated to exclude bounding or unrealistic assumptions. Generic physical parameters were defined to represent real conditions and expected variability across the United States. Behavioral and metabolic parameters were defined to represent the expected variability between individuals within the defined screening group (the generic critical group).

The purpose of these definitions was two-fold: first, to provide a basis for screening; second, to provide information for more complex decommissioning situations where a clear understanding of the modeling assumptions and construction of the parameters is needed to support changes that lead to more realistic dose assessments.

1.4 Expectations for Interim Use of This NUREG

It is expected that, as this approach is applied to decommissioning decision making, changes may need to be made to the models, scenarios, and/or parameters. Licensees are encouraged to carefully evaluate this approach and provide information to the NRC regarding the need for changes. Specifically, the distributions developed for the model parameters are expected to be modified to incorporate new information, and the current broad screening is expected to be further developed into multiple screens based on regional or license-type considerations.

2.0 Overview of the decision framework

A decision framework has been developed which provides a methodology for dose assessments used in demonstrating compliance with the radiological criteria of Subpart E of 10 CFR 20. Section 2.1 of this NUREG describes the rationale for the decision framework, Section 2.2 describes a phased approach for using the decision framework (i.e., moving from generic screening to site specific analyses), Section 2.3 describes the interrelationship of this NUREG with the regulatory positions of Regulatory Guide DG-4006, “Demonstrating Compliance with the Radiological Criteria for License Termination,” and Section 2.4 describes how the framework can be applied to the wide range of NRC licensees.

2.1 Rationale for the decision framework

A logical, consistent decision process is viewed as a useful tool that will support licensee planning of decommissioning activities and NRC review of license termination requests. To support this process, this NUREG describes a decision methodology, or “framework,” to support implementation of the dose assessment requirements in Subpart E.

Dose assessments are used to demonstrate compliance with the criteria of Subpart E and generally rely on the use of site characterization and modeling and analytical tools. The principal components of the dose assessments are: (a) models for transport of radionuclides through the environment to a receptor, and (b) the parameters used in those models. In these dose assessments, a reasonable treatment of uncertainty is needed to provide the regulator with the confidence that the actions taken and the decisions made to terminate the facility license are consistent with the regulations.

The steps and decision points of the decision framework support assessment of the entire range of dose modeling options from which a licensee may choose, whether it involves using generic screening parameters, changing parameters, or modifying pathways or models. The decision framework, including its steps and decision points, is illustrated in Figure 1.

2.2 Phased approach in using the decision framework

2.2.1 Contents of the phased approach in using the decision framework

To facilitate the preparation and evaluation of the dose assessments, this NUREG describes a phased approach to decision making for license termination. A phased approach is necessary because of the very wide range of levels of contamination and complexity of analysis and potential remediation necessary at NRC-licensed sites. The phased approach consists of generic screening and of making use of site specific information as appropriate. These phases are described in broad terms below:

1) <u>Generic screening:</u> In this phase, licensees would demonstrate compliance with the dose criteria of the rule by using: (a) pre-defined models, and (b) generic screening parameters.

   Pre-defined models which use generic exposure scenarios and pathways are based on the NUREG/CR-5512, Volume 1, methodology and can be used with minimal justification by licensees who are applying generic screening scenarios and parameters using the DandD software. The generic scenarios and pathways of the pre-defined models provide the licensee with a simple method to demonstrate compliance using little site-specific information.

The pre-defined models and generic screening parameter distributions are used to calculate a reasonably conservative range of doses that the average member of the screening group[1] could receive. This information was used to develop default deterministic parameters for the DandD model.

It is anticipated that many of NRC's licensees will be able to use generic screening to demonstrate that their site is acceptable for license termination.

2) Use of site specific information as appropriate: If compliance cannot be demonstrated using generic screening , then licensees should proceed to the next phase of analysis in which defensible site specific values are obtained and applied. Examples of site-specific features that may require modeling beyond the defaults include (but are not limited to) known groundwater contamination, large quantities of contaminated material (such as slag piles), or buried wastes. Depending on the complexity of the site contamination, the licensee can use site specific information by:

   (a) using the NRC's pre-defined models but replacing generic screening parameters with site-specific parameter values to allow site specific factors to be taken into account. Thus, the dose estimates would be more realistic, but will still be conservative for a particular site based on the use of the pre-defined models. or

   (b) using both site-specific parameter values and site-specific model assumptions;

   (c) using some combination of a and b and also remediating the site;

   (d) using some combination of a, b, and c, and also restricting use of the site

   In any of the cases a - d, site specific data are used to support modifying or eliminating a particular scenario or pathway, or to demonstrate that a parameter or group of parameters can be better represented by site specific values. Alternative exposure scenarios may be appropriate based on site-specific factors that affect the likelihood and extent of potential future exposure to residual radioactivity.

   Thus use of the framework for these situations can range from fairly simple site assessments to fairly complex analyses. In either case, use of all 12 steps of the framework in Figure 1 would likely be used in these cases, although the range of options analyzed in Step 8 can be fairly simple (e.g. modification of parameters) to fairly complicated (e.g., use of restrictions on site use).

2.2.2 General concepts regarding the phased approach

The following general concepts apply to using the phased approach with the decision framework:

[1]The screening group is a generic surrogate for the site-specific critical group.

a) The approach provides a process for screening sites and for directing additional data collection efforts where necessary. It provides the licensee with a variety of options for performing dose assessments from simple screening to more detailed site specific analyses.

   The framework is designed such that the level of complexity and rigor of analysis conducted for a given site should be commensurate with the level of risk that the site poses. Although use of the framework would normally encompass Steps 1 through 5, and steps 6 and 7, the amount of work that goes into each of these steps should be based on the expected levels of contamination and the health risks they pose. Note that in this framework, all sites may start at the same level of very simple analyses (not a requirement for successful implementation), but it is expected that only certain sites would progress to very complex dose assessment and options analyses. Some sites may not need to conduct any options analyses (Step 8) and some sites may need to evaluate a limited set of relatively simple and inexpensive options. For example, a site with a contained source of contamination that is obviously simple to remove would not spend time analyzing large suites of alternative data collection and remediation options. On the other hand, a site with high levels of contamination that are widely distributed may use this process to analyze a variety of simple and complex options to define the best decontamination and decommissioning strategy.

   Thus, the approach ensures that the licensee's efforts and expenses would be commensurate with the level of risk posed by the site;

b) The licensee would not need to start the process with generic screening but may move directly to use of site specific information, as appropriate.

c) For the process to work efficiently, the licensee is encouraged to involve the NRC from the very first step through the end of the decision making process.

2.3 Interrelationship of the framework with the regulatory positions of Regulatory Guide DG-4006, "Demonstrating Compliance with the Radiological Criteria for License Termination"

Use of the decision framework of this NUREG should be done in an integrated manner with other aspects involved in terminating a license and releasing a site. These include general dose modeling provisions, meeting ALARA requirements, performing final status survey procedures, and planning for restrictions on site use. Acceptable approaches for each of these items are contained in Regulatory Positions 1, 2, 3, and 4, respectively, of Regulatory Guide DG-4006. Briefly, DG-4006 provides regulatory positions on:

1) Dose Modeling - This section provides staff positions for demonstrating compliance with the dose criteria in Subpart E to 10 CFR Part 20. In particular, it addresses dose modeling methods to relate concentrations of residual radioactivity to dose to the average member of the critical group in order to demonstrate that the dose criteria of 10 CFR 20.1402 and 20.1403 have been met. This section references NUREG-1549, as providing an acceptable methodology for calculating dose.

2) Final Status Surveys - This section provides staff positions on acceptable methods for conducting a final radiation status survey for buildings and soil prior to terminating the

license. This section references NUREG-1575, “Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM),” NUREG 1505, “A Nonparametric Statistical Methodology for the Design and Analysis of the Final Status Decommissioning Survey,” and NUREG 1507, “Minimum Detectable Concentrations with Typical Radiation Survey Instruments For Various Contaminants and Field Conditions,” as containing acceptable methods for conducting final status surveys.

3) ALARA - This section provides staff positions on acceptable methods to demonstrate that residual radioactivity has been reduced to levels that are ALARA. It provides an approach for estimating benefits in terms of collective dose resulting from a remediation action and for estimating costs of remediations. In addition, it provides staff positions on acceptable methods to demonstrate that further reductions in residual radioactivity are not technically achievable, could cause net public or environmental harm, or are prohibitively expensive.

4) Restricted Use - This section provides staff positions on acceptable methods for terminating a license under restricted conditions, including establishing adequate institutional controls, demonstrating adequate financial assurance for release under restricted conditions, and seeking public input on the restrictions.

As noted above, use of this NUREG should be done in an integrated manner with the regulatory positions of DG-4006 during the license termination process. For example:

1) A licensee planning for license termination should use the dose modeling positions in Regulatory Position 1 of DG-4006 (and as referenced to this NUREG) to assess whether estimated doses at the site will meet the unrestricted use dose criterion of 25 mrem/yr. As explained in Section 2.2 above, this assessment can be made either by use of generic screening or by use of site-specific analyses. As also described in Section 2.2 above and in more detail in Chapters 3, 4, and 5 of this NUREG, the decision framework will also assist a licensee in determining whether additional remediation is necessary or whether it may have to consider releasing the site under restricted conditions (see Item #5 below).

   Regulatory Position 1 on dose modeling (and this NUREG) can be useful to licensees in estimating the concentration of the residual radioactivity distinguishable from background which would result in a total effective dose equivalent of 25 mrem/yr to an average member of the critical group. This value is referred to throughout the guide as the “derived concentration guideline” DCGL.

2) A licensee should also refer to the positions on ALARA in Regulatory Position 3 of DG-4006 during its planning process to assess whether the levels present at the site are ALARA.

3) The estimated DCGL, from #1 above, can be used in planning the final status survey described in Regulatory Position 2 of DG-4006 (and in the referenced NUREGs) to determine whether there is sufficient confidence to conclude that the contamination in each of the survey units at the site is less than the dose criteria in Subpart E to 10 CFR Part 20.

4) As a result of the dose assessment, it may be necessary to release the site for restricted use. If this is the case, the licensee should follow the positions of Regulatory Position 4

of DG-4006 regarding the type of institutional controls needed, the associated financial assurance, and the activities necessary to seek public input on the controls. Before terminating the license, a licensee in this situation would also use the positions on the final status survey in Regulatory Position 2 of DG-4006 to determine if the DCGL corresponding to restricted use had been met.

Chapters 3, 4, and 5 of this NUREG make reference as appropriate to the regulatory positions of DG-4006 to illustrate the interrelationship of this NUREG with the regulatory guide.

2.4 Use of the framework for the wide range of NRC licensees

Chapters 3, 4, and 5 provide descriptions of each of the framework steps (see Figure 1) in some detail, and how they integrate to define a process for moving through the framework to define a license termination strategy. It is important to note that these chapters and the process of considering them by any particular licensee should be fluid, that is a licensee may, in considering options for dose assessment and license termination, use any one of the chapters or all of them.

Detail on each step is provided in Chapter 3 for sites that use the generic screening approach, in Chapter 4 for sites that use an approach of incorporating site specific information, and in Chapter 5 for more complex situations. Licensees using codes and modeling approaches other than generic screening should use Chapters 4 and 5. Chapter 4 is presented separately from Chapter 5 to account for the wide range of NRC licensees that might choose to use site specific information. This may cause some repetition of information but it is expected to be most useful to licensees to be presented in this manner.

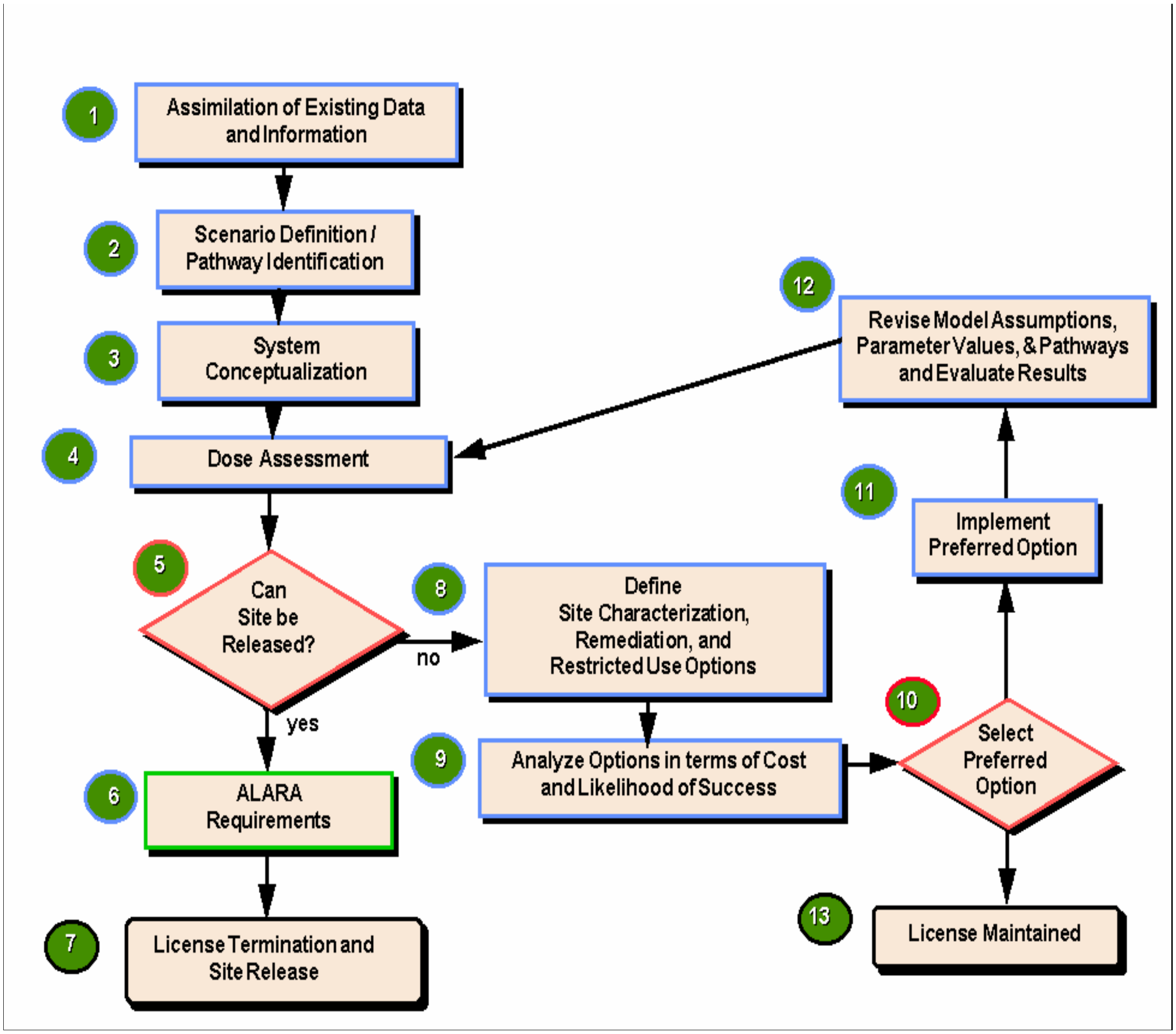

Figure 1 Decommissioning and License Termination Framework

3.0 Use of the Framework for Licensees That Use Generic Screening

As noted above, this chapter describes the use of the framework for licensees that use the generic screening approach described in Section 2.2.1 . In general, a licensee with little contamination would follow Steps 1 through 7 of the framework of Figure 1. Such licensees would likely include those NRC licensees with contained or short-lived radionuclide sources that have small amounts of building or soil contamination. An example of the use of the framework for such a situation is given in Appendix G as Case 1. Licensees with more complex decommissioning situations may also find a screening approach useful for portions of their sites with only small amounts of contamination. Licensees of this type would step through the framework as follows:

3.1 Step 1:

This step involves gathering and evaluating existing data and information. Licensees should check their records to determine the types and amounts of radioactive material they possessed on their site. They should also gather information about any surveys and leak tests that had been performed, as well as any records important to decommissioning as described in 10CFR Parts 30.35, 40.36, 50.75, 70.25, and 72.30, as appropriate. This will enable them to quantify the amount of contamination present at the site.

3.2 Step 2:

This step involves defining the scenarios and pathways that are important for the site dose assessment. For a licensee using the generic screening parameters, this step has already been completed by the NRC, based on the generic scenarios and pathways for screening that have been defined and described in NUREG/CR-5512, Volume 1. Information on generic scenarios and pathways is presented in Appendix C.1.

3.3 Step 3:

This step involves system conceptualization, which includes conceptual and mathematical model development and assessment of parameter uncertainty. For a licensee using generic screening, this step has already been completed by NRC, using the models described in NUREG/CR-5512, Volume 1, and implemented in the DandD software. Information on generic models for system conceptualization is presented in Appendix B.1.

Thus, a licensee using generic screening could use the DandD software containing pre-defined models and default parameters. The minimum justification for the use of the default models, scenarios, and parameters would consist of a statement that no conditions exist at the site, outside those incorporated in the default scenarios and modeling assumptions, that would cause the calculated dose to increase. Examples of site-specific features that may require modeling beyond the defaults include (but are not limited to) known groundwater contamination, large quantities of contaminated material (such as slag piles), or buried wastes.

3.4 Step 4:

This step involves the dose assessment for the site. For generic screening, the licensee can use the generic screening model and default parameters which have already been developed by the NRC to compare against the site contamination levels obtained in Step 1, by running DandD with the appropriate site specific source term.

3.5 Step 5:

This is the first major decision point in the framework and involves answering the question of whether the dose assessment results of Step 4 are less than the dose criterion of 25 mrem/y in 10 CFR 20, Subpart E. For a licensee using DandD with default parameters and site-specific source term, the licensee would find either that:

a) The result in Step 5 is that the calculated dose is less than 25 mrem/y. **If this is the case, proceed to Step 6**

b) The result in Step 5 is that the calculated dose is greater than 25 mrem/y. If this is the case, it means that the contamination at the site is such that the licensee cannot use the generic screening approach to terminate the license. To terminate the license, the licensee should first evaluate other options such as incorporating site specific information into the dose assessment. Thus, if this result is found, **the licensee should proceed to Chapters 4 or 5, which describe acceptable methods for incorporating site specific information into the dose assessment.**

3.6 Step 6:

If the result in Step 5 is that the calculated dose is less than 25 mrem/y, the licensee can proceed to satisfy ALARA requirements, if not already addressed (see Section 4.0 of DG-4006)

3.7 Step 7:

For this step of the process refer to DG-4006 and NUREG-1575 for guidance on performing the final status survey and other steps necessary prior to license termination.

4.0 Use of Site Specific Information to modify model parameters

This chapter describes a method for incorporating site specific information into a dose assessment. As described in Section 2.2, there are a wide range of options for using site specific data ranging from modifying parameters, to modifying models, to remediating the site, to restricting site use. This chapter describes an approach for modifying model parameters without further consideration of other options such as modifying scenarios or models. This chapter is prepared separately from Chapter 5 (which includes a more in-depth evaluation of options) because it is thought that a number of licensees will have relatively low levels of contamination and by changing default screening parameters the model will be more representative of their site.

While this chapter describes the option of changing modeling parameters, it is not intended to limit the options a licensee may pursue. For example, it is possible that a licensee could combine obtaining additional site data to revise parameters with remediating a site, or could even proceed directly to remediate a site. This chapter provides information for licensees who, possessing relatively simple contamination patterns, have used a correspondingly simple consideration of their options to conclude that modifying parameters from the screening values will provide a simple, cost effective means to comply with the dose criteria of Subpart E. It should be further noted that licensees who proceed through the framework as outlined in Chapter 4 can still proceed to Chapter 5 if necessary. A licensee who is uncertain of what option is most appropriate should proceed to Chapter 5.

An example of the use of the decision framework for a dose assessment where only model parameter modification is used is given in Appendix E as Case 2.

4.1 Steps 1- 5

Licensees using this approach are assumed to have little information about their site initially and are assumed to go though the process of generic screening to determine if their site can be released. Thus, Steps 1 - 5 would be the same as described in Chapter 3. It is further assumed that these licensees on their initial pass would end up in Step 5b in which the contamination at the site is such that the licensee cannot use the generic screening approach to meet the dose criteria of Subpart E. Thus, rather than proceeding to Step 6 and 7, these licensees would proceed to Step 8.

4.2 Step 8 - Define Site Characterization, Remediation, And Restricted Use Options

The purpose of Step 8 is to define options for proceeding with the license termination process. These options are presented here as information for licensees in planning their dose assessments. As described in Chapter 1 above, a well thought out consideration of options for compliance with Subpart E and for submittals to NRC will enhance the process of decision-making on both the licensee's and the NRC's part by allowing the licensee to make decisions in a timely manner that are both cost-effective and have a sound technical basis.

There are basically three options that the licensee could apply either alone or in combination:

a) Option 1 - Activities that reduce the calculated dose through use of source terms, pathways, models, and/or parameters that better represent the site based on some additional site information gathering or characterization,

b) Option 2 - Activities that reduce contamination (remediation), and

c) Option 3 - Activities that reduce exposure (land-use restrictions).

Chapter 4 assumes that the licensee will proceed to use Option 1. Most sites would perform an analysis of the options that is relatively simple and arrive at Option 1 because the nature of the contamination or the site conditions appear likely to support a lower estimated dose. Licensees might elect to use Option 1 before proceeding to other more complex activities such as excavating, transporting and disposing of soil from the site that would be involved in Option 2 or establishing institutional controls for restricted use that would be involved in Option 3. An example of a process of considering options that a licensee might use before arriving at a decision to use Option 1 is shown in Table 5.2.

For Option 1, licensees should do the following:

a) <u>Review the parameters in the NUREG/CR-5512 model and what they represent:</u> The parameter distributions and their rationale are presented in Attachment 1. The rationale for parameter selection for the generic screening approach is presented in Section 2.2.1 of this NUREG.

b) <u>Consider how to modify the parameters to incorporate site specific information and determine the data needs to modify the parameters:</u> Attachment 1 provides information regarding the valid ranges for site specific parameter changes that a licensee could propose without the need for an additional uncertainty analysis. Appendix E provides information on how to modify the parameters used in the dose assessment .

4.3 Step 9 - Analyze Options in terms of Cost and Likelihood of Success

This step involves the analysis of options in terms of cost and the likelihood of success. As noted above in Step 8, the purpose of this step is to provide information for the licensee so that the evaluation of options considers both the probability that a desired result will be achieved, (i.e., meeting the criteria of Subpart E), and that achieving the desired result is done in a cost-effective manner.

For the licensee choosing Option 1, Step 9 should consist of the following:

a) an evaluation of the level of detail and information sources to use to better estimate values for the model parameters that will be updated with site-specific information. Such an evaluation is important because there are many options for modifying parameters which range in cost and complexity depending on whether low cost information is easily accessible or if it will require expensive or specialized laboratory analysis. This evaluation can be done by reviewing the parameters in Appendix E and Attachment 1.

b) The cost needed to review each parameter should be estimated, along with a qualitative estimate of the likelihood that the approach will be successful in meeting the desired endpoint (i.e., meeting the criteria of Subpart E). The analysis should also address the uncertainty associated with each potential outcome.

If the activity is successful, then the revised calculation of dose will meet the Subpart E criteria, no follow on activities are necessary, and no other significant costs would be incurred. On the other hand, if the activity is unsuccessful, the eventual total cost will be the cost to conduct the activity plus the cost to conduct any necessary follow-on activities to get the dose to an acceptable level.

c) A decision should be made regarding the method for gathering information to revise parameters based on a and b, above. Note that *actual* success or failure of this effort will not be realized until the second iteration of Steps 4 and 5 when the revised parameter values are incorporated and the dose is recalculated.

4.4 Step 10 - Select Preferred Option

The activities in Step 9 provide information for the licensee using Option 1. In this case, at this step, the licensee would choose the method for revising the parameters given the cost, timeliness and likelihood of success.

4.5 Step 11 - Implement Preferred Option

Under Step 11, the preferred option is implemented. The licensee obtains the information necessary to support revisions to the parameters that will be modified.

4.6 Step 12 - Revise Model Assumptions, Parameter Values, and Pathways

Under Option 1, the parameter values for the pre-defined models are revised as appropriate. Documentation of any site survey results, parameter data, or laboratory tests may be useful to support a future request for license termination. The process that the licensee should go through to justify new parameter values or refine parameter distributions is presented in Appendix E.

4.7 Reiteration of Step 4:

The revised parameter values are used in iteration 2 of the dose assessment. For the licensee only changing parameters, the original default model assumptions and pathways would remain unchanged.

4.8 Reiteration of Step 5:

The revised dose assessment is evaluated to determine if the calculated dose meets the requirements in 10 CFR 20, Subpart E. For a licensee using site specific information to modify the parameter values, the licensee would find either that:

a) The result in Step 5 is that the calculated dose is less than or equal to the 25 mrem/y dose criterion of 10 CFR 20.1402. **If this is the case, proceed to Step 6**

b) The result in Step 5 is that the calculated dose is greater than the 25 mrem/y dose criterion of 10 CFR 20.1402. If this is the case, it means that the contamination at the site is such that, based on the pre-defined models and scenarios, use of a limited number of more realistic parameter values is not sufficient to demonstrate compliance with Subpart E. In order to terminate the license, the licensee may need to evaluate a wider range of options, including such things as refining the source term, using more realistic models or scenarios, or possibly remediation or restriction of site use. Since the initial simple approach of revising parameters has not proven acceptable, **licensees should proceed to Chapter 5 and use the framework steps applicable to further analysis of options**. Licensees are encouraged to actively work with the NRC during this step to evaluate the appropriateness and adequacy of the analyses before moving on and expending resources on follow on steps.

4.9 Step 6 - ALARA Requirements

If the result in Step 5 is that the 25 mrem/y criterion has been met, the licensee can proceed to satisfy ALARA requirements, if not already addressed. Guidance on acceptable approaches to demonstrating compliance with the ALARA requirements can be found in Section 3 of DG-4006. The licensee is encouraged to actively work with the NRC to discuss alternative ALARA actions under this step prior to implementing any actions.

4.10 Step 7 - License Termination and Site Release

For this step of the process refer to DG-4006 and NUREG-1575 for guidance on performing the final status survey and other steps necessary prior to license termination.

5.0 Use of the framework for licensees that use Site Specific Information and Consider a range of Options for using that information

This chapter describes the use of the framework for licensees that may want to use site specific information in their dose assessment. As described in Section 2.2, there are a range of options for using site specific data. Chapter 4 discussed the framework for those licensees that want to simply modify model parameters. However, there may be licensees that will want to consider other options, such as:

a) changing the models, scenarios, pathways, and/or parameters used for assessing nuclide behavior to support release of the site for unrestricted use,

b) remediating the site by removal of soil or structures,

c) restricting future use of the site under the requirements of 10 CFR 20.1403,

d) some combination of a, b, or c.

Licensees may choose not to use generic screening, preferring instead to immediately utilize as much existing site-specific information as possible. Therefore the discussion of the use of the framework for these sites begins with the licensee using site specific information in Steps 1 - 4 rather than using the generic screening approach of Chapter 3 (alternatively, even a licensee with significant site-specific information may find it useful to start with the generic screening in the initial iteration (see Section 4.1)). Licensees using this approach would step through the framework as follows:

<u>5.1 Step 1 - Assimilate Existing Data and Information:</u>

This step involves gathering and evaluating existing data and information. Licensees should check their records to determine the types and amounts of radioactive material they possessed on their site. They should also gather information about any surveys and leak tests that had been performed, as well as any records important to decommissioning as described in 10CFR Parts 30.35, 40.36, 50.75, 70.25, and 72.30, as appropriate.

Data gathered in this step are used to support Step 3 which is development of a conceptual model, and model assumptions and model parameter values. As described above, the licensee has 3 options in this analysis:

(1) use the pre-defined DandD models and the specified set of site-specific parameter values

(2) use other existing models and codes and site-specific parameter values

(3) develop site-specific models and codes and accompanying parameter values

Additional information is needed to support and defend the conceptual model of Step 3 if models other than DandD are used or if site specific parameter values are used. Methods for obtaining the necessary additional information to support the site specific parameters and models used are described in Appendix E.2.

5.2 Step 2 - Scenario Definition/Pathway Identification:

This step involves defining the scenarios and pathways that are important for the site dose assessment. In this step, the licensee defines potential human activities and identifies migration and exposure pathways that need to be considered. Each of the site release conditions defined in Subpart E (unrestricted use or restricted use) involve potentially different considerations with respect to human activities on or near the site (the critical group) and radionuclide migration pathways. These should be considered as follows:

a) Scenarios are defined as reasonable human activities and future uses of the site. The site-specific critical group for any scenario can be based on historical, current, and projected future land use or the physical characteristics of the site.

b) The definition of scenarios and identification of pathways can be generic or site specific.

Generic scenarios, critical groups, and pathways are described in Appendix C.1. Appendix C.2 describes a method for selecting appropriate critical groups for a site and developing site specific scenarios and pathways.

5.3 Step 3 System Conceptualization:

System Conceptualization, as defined here, includes conceptual and mathematical model development and assessment of parameter uncertainty. This assessment of uncertainty includes a process of evaluating the level of uncertainty associated with a specific site and the quantification of that uncertainty. In order to manage the treatment of uncertainty associated with dose assessment at a given site, the four steps of scenario definition, pathway identification, model development, and assessment of parameter uncertainty are treated as a hierarchy, moving from the former of these to the latter.

As with the pathways, conceptual and mathematical models have been defined for the NUREG/CR-5512 methodology and these models (implemented in the DandD code) are acceptable for performing dose assessments. Information on the generic models is contained in Appendix D.1. In addition, Appendix D.1 provides information for use in evaluating whether or not the generic models are appropriate given the assumptions made in NUREG/CR-5512 and the nature of the site.

If the licensee chooses to develop a site-specific model, then the licensee would need to justify the model and associated parameters. Information on methods for developing site specific models is contained in Appendix D.2, including information on development of the model (D.2.1), use of a deterministic or probabilistic approach (D.2.2), and selection of codes (D.2.3).

5.4 Step 4 - Dose assessment

This step involves the dose assessment for the site, which means running the DandD or equivalent software with the appropriate site specific source term.

In this step, the licensee will calculate potential doses using mathematical representations of the conceptual models. This step involves the execution of the numerical model(s) that implement the mathematical equations and will provide the basis for assessing compliance with the individual dose criteria. If the licensee chooses to perform a probabilistic analysis, they will also perform an analysis of the impact of uncertainty on the model output. In doing so, they would include the propagation of uncertainty in parameters through exposure models and would provide a quantitative representation of the uncertainty in the dose given those models and parameters.

NRC has implemented the default scenarios, critical groups, pathways, model assumptions and parameter values from Steps 2 and 3 in the DandD code. The licensee has the option of using DandD for the dose assessment, under the conditions discussed in Appendix D.1.

Information on methods to perform site specific dose assessments is contained in Appendix B.2.1 through B.2.3.

5.5 Step 5 - Can the site be released

The dose assessment using the site specific information generated in Steps 1 - 4 is evaluated to determine if the calculated dose meets the requirements in 10 CFR 20, Subpart E. For a licensee using site specific information, the licensee would find either that:

a) The result in Step 5 is that the calculated dose is less than or equal to the 25 mrem/y dose criteria of 10 CFR 20.1402. **If this is the case, proceed to Step 6.**

b) The result in Step 5 is that the calculated dose is greater than the 25 mrem/y dose criteria of 10 CFR 20.1402. If this is the case, it means that the contamination at the site is such that the licensee would need to consider additional options to terminate the licensee and demonstrate compliance with Subpart E. In order to terminate the license, the licensee may need to evaluate a wider range of options, such as refining the source term, using more realistic models or scenarios, or possibly remediation or restriction of site use. Thus, if this result is found, **the licensee should proceed to Step 8**. The licensee is encouraged to actively work with the NRC during this step to evaluate the appropriateness and adequacy of the analyses before moving on and expending resources on follow on steps.

5.6 Step 8 - Define Site Characterization, Remediation, And Restricted Use Options

The purpose of this step is to for the licensee to better define its options for proceeding with the license termination process. These options are presented here as information for licensees in planning their dose assessments and their submittals to the NRC. As described in Chapter 1 above, a well thought out consideration of options for compliance with Subpart E and for submittals to NRC will enhance the process of decision-making both on the licensee's and the NRC's part by allowing the licensee to define the most effective and cost-efficient decontamination and decommissioning strategy. Section 5.6.1 presents the principal options and Section 5.6.2 present the actions that a licensee should take in considering these options. Table 5.1 presents a summary of a licensee's possible process for considering the options.

5.6.1 Defining options

There are basically three options that the licensee could use. Generically, the options are:

1) Option 1 - Activities that lower the estimated dose by incorporating site-specific or regional information (information/data collection)

2) Option 2 - Activities that lower dose by reducing contamination (remediation)

3) Option 3 - Activities that lower dose by restricting site use

The options can be implemented singly or in combination, and the combinations can be performed either in parallel or in series to provide the optimal solution. In addition, there could be a large number of combinations of site characterization data collection options. Examples of combined alternatives include:

* site characterization to revise the source term (Option 1) combined with remediation (Option 2) followed by unrestricted release,

* site characterization to revise the source term (Option 1) combined with literature/database review to support default parameter replacement (Option 1) followed by unrestricted release,

* site characterization to revise the source term (Option 1) combined with literature/database review to support default parameter replacement (Option 1) combined with remediation (Option 2) followed by unrestricted release,

* remediation (Option 2) combined with land-use restrictions (Option 3) followed by restricted release. Another example is the application of land-use restrictions to some portions of the site and remediation and unrestricted release to other portions of the site to reduce long-term maintenance, monitoring and assurance costs.

5.6.2 Specific Licensee Actions Under the Options

A licensee in Step 8 may want to consider the options in a manner similar to the following (Table 5.1 presents an example of a licensee's possible process for considering the options):

1) **<u>Option 1 - Activities that lower dose (information/data collection and revision of source term, parameters, and/or models)</u>**

   This option would be pursued if existing information does not result in the dose criterion being met, but further reduction of uncertainties and conservatism through use of site-specific data are likely to result in a calculation of dose that meets the criteria of Subpart E. Specifically, these activities are data and information collection activities that would result in a reduction of uncertainty in the calculated doses through use of source terms, pathways, models, and/or parameters that better represent the site.

   In Option 1 licensees should do the following:

   a) <u>Review the parameters in the NUREG/CR-5512 model and what they represent:</u> The parameter distributions and their rationale are presented in Attachment 1. The rationale for parameter selection for the generic screening approach is presented in Section 2.2.1 of this NUREG.

b) Consider how to modify the parameters to incorporate site specific information and determine the data needs to modify the parameters: Attachment 1 provides information regarding the valid ranges for site specific parameter changes that a license could propose without the need for an additional uncertainty analysis. Appendix E provides information on how to modify the parameters used in the dose assessment .

c) Consider whether modification of the critical group is appropriate: Various site uses and scenarios can be postulated within the limits of reasonable future uses for the site and surrounding properties. Licensees may choose to specifically define the critical group. Initial iterations of the decision process described in this document may simply involve use of the screening scenarios and screening groups listed in the previous section. Subsequent iterations may involve site specific scenarios and critical groups (referred to as "site specific critical groups"). Background information on critical groups is contained in Appendix C.3 and information on developing site specific scenarios and critical groups is in Appendix C.2

(2) **Option 2 - Activities that lower dose by reducing contamination (remediation)**

This option involves remediation activities that remove actual contamination from the site. Option 2 results in actual reduction in exposure by reducing the quantity of residual radioactivity remaining on the site.

(3) **Option 3 - Activities that lower dose by reducing exposure (land-use restrictions)**

This option would be pursued if the licensee is considering restricting use of the site as a means of terminating the license. If Option 3 is pursued, the licensee is required by 10 CFR 20.1403 to conduct the following additional analyses and activities: (1) demonstrate that achieving unrestricted release is not ALARA, (2) provide legally enforceable institutional controls that would limit the exposure to individuals to 25 mrem/y, (3) provide financial assurance for the controls, and (4) seek advice from those in the community who may be affected by the decommissioning. In order to comply with these requirements, a licensee should do the following as part of considering Option 3:

a) Because use of Option 3 requires a demonstration to the NRC that further reduction in dose levels to unrestricted use is not ALARA (i.e. NRC would prefer unrestricted use), licensees should fully evaluate unrestricted release for the first iteration through the decision process by fully considering Option 1 and/or Option 2. Any site-specific information gathered to support Options 1 or 2 can be used in a later iteration analyzing restricted release.

b) The dose modeling for Option 3 should include as much site-specific information (gathered as part of Option 1) as necessary to provide a reasonable evaluation of future impacts, both with and without institutional controls in effect, to show compliance with restricted release criteria, i.e., the screening parameters are not sufficient to support a decision to select restricted use

c) The dose assessment under Option 3 should evaluate site specific critical groups as follows:

(1) the site specific critical group as defined by the institutional controls used to restrict land use. For example, if a site is restricted to industrial use, the site specific critical group would be the group of workers who occupy the building and are “reasonably expected to receive the greatest exposure to residual radioactivity for any applicable set of circumstances.”

(2) the site specific critical group possibly affected by groundwater transport of radionuclides offsite (this critical group will only be important for a very limited number of sites with existing ground water contamination, or with contamination which may impact an offsite drinking water supply).

(3) the site specific critical group which would be exposed in the event of failure of institutional controls and which thus effectively has access to the site as if the site were unrestricted. The site specific critical group in this case would be the resident farmer scenario used in generic screening, unless the licensee is able to define and defend an alternate site specific critical group and scenario.

d) Conduct the regulatory activities that will need to be completed prior to license termination. Guidance on these aspects is found under Regulatory Position 4 of DG-4006.

For a set of hypothetical options, Table 5.1 provides an example of how a licensee might identify and summarize their options. In making such a table, column 1 would be the expected (estimated) outcome following the activities in each of the options. Column 2 of the table represents the expected outcome. Column 3 defines the action that would be needed.

Table 5.1 - Example Options Definition Table

Expectation	**Effect on Dose**	**Action**
Source is believed to be of lower concentration than currently modeled	Simulated dose expected to decrease as concentrations decrease	Collect field data to better characterize source distribution
Experimentally measured kd for this site expected to be higher than default value	Simulated dose expected to decrease as availability to the receptor is decreased	Collect laboratory data to reduce uncertainty in the kd
Soil permanently removed to decrease source concentrations	Available mass of contaminant decreases, hence simulated dose would decrease	Remediation by soil removal

Table 5.1 - Example Options Definition Table		
Expectation	**Effect on Dose**	**Action**
Controls are expected to remain in place for the duration of the compliance period (if controls fail, simulated doses are between 25 mrem and 100 mrem)	restrictions will limit access to disposal areas on site while controls are in place; simulated dose will decrease	Dispose of waste and stabilize on current site and apply for restricted release
Controls are expected to remain in place for the duration of the compliance period (if controls fail, simulated doses are between 25 mrem and 100 mrem)	restrictions will limit uses for site while controls are in place to limit exposure time and pathways to individual; simulated dose will decrease	Set land use restrictions and apply for restricted release

5.7 Step 9 - Analyze Options in terms of Cost and Likelihood of Success

This step involves the analysis of options in terms of cost and the likelihood of success. As noted above in Step 8, the purpose of this step is to provide information for the licensee so that the evaluation of options considers both the probability that a desired result will be achieved, (i.e., meeting the criteria of Subpart E), and that achieving that result is done in a cost-effective manner.

Step 9 should be performed in the following manner:

a) An analysis of the potential outcome should be performed for each of the options identified in Step 8.

b) The analysis of outcomes should be no more complex than necessary to support a reasonable and cost-effective evaluation of the options.

c) The cost necessary to complete each option should be estimated, along with the likelihood that the option will be successful in meeting the desired endpoint (meeting the criteria of Subpart E). The analysis should also address the potential for both success and failure of achieving the desired endpoint.

   For example, if the licensee chose to spend money to collect some additional information on some specific soil properties at their site and spend some money on remediating a small portion of the site, and after this were able to defensibly demonstrate that the dose was below 25 mrem, then their activities would have been successful and the site could be released as unrestricted.

   Analysis of options should include explicit evaluation of the associated regulatory requirements. This may mean that certain options are not allowed until specific conditions are met (e.g., whether it is ALARA or whether there is a potential for environmental harm. With regard to costs, the licensee should consider that if the option(s) selected are successful, the license will be released and further costs will be minimized. However, if the selected option(s) are unsuccessful, it may be necessary to perform additional characterization or remediation, or there may need to be an evaluation of restricted use (with its associated costs).

This step should also include ALARA considerations based on the guidance in DG-4006, in terms of cost/benefit calculations.

d) A list should be prepared of the options with their corresponding cost, qualitative probability of success (i.e., meeting Subpart E criteria), and other important considerations. An example of such a list is shown in Table 5.2.

e) Make a decision regarding the preferred option (Step 10). In some cases, the decision regarding the preferred option will be obvious, however, additional analysis may be needed for sites with complex issues. At this point in the decision process, the idea is not to permanently eliminate options from further consideration, but rather to select the optimum approach based on the current state of knowledge.

Note that *actual* success or failure will not be realized until the second iteration of Steps 4 and 5.

The licensee in making a decision regarding the options should consider the following:

a) for Option 1, the likelihood of successfully collecting the data that is needed to reduce the dose from an unacceptable estimated dose to an acceptable estimated level;

b) for Option 2, the likelihood that contamination will be reduced to a level that will result in acceptable dose; or

c) for Option 3, the likelihood that a specified restriction will be durable and effective in reducing exposure for the necessary time period.

An example of how the options could be organized is provided in Table 5.2 (for a set of hypothetical alternative actions).

The decision process could include other factors in addition to the probability of success and cost (e.g., time to complete the activity, environmental justice, etc.). These other influencing factors can be articulated and presented as part of the results of each of the options defined in the options analysis table. The result of Step 9 should be a logically represented list of options and the corresponding cost, likelihood of site release, and other important considerations. This analysis will provide information necessary in Step 10.

Table 5.2 - Example Options Analysis Table (Hypothetical)				
Alternative Action	**Cost (if successful)**	**Cost (if unsuccessful)**	**Probability of Success**	**Required Outcome**
Collect field data to better characterize source distribution	$$		high	dose less than 25 mrem
Collect laboratory data to reduce uncertainty in Thorium Kd	$$		high	dose less than 25 mrem
Collect literature data to defend alternative parameters	$		medium	dose less than 25 mrem
Remediation by soil removal	$$$		high	dose less than 25 mrem
Stabilize or dispose of waste on site and apply for restricted release	$$		medium	dose w/ controls less than 25 mrem; dose w/o controls less than 100 mrem
Set land use restrictions and apply for restricted release	$$		low	dose w/ controls less than 25 mrem; dose w/o controls less than 100 mrem

5.8 Step 10 - Select Preferred Option

In Step 10, the licensee chooses the option that will be pursued given the cost, timeliness and likelihood of success, and regulatory requirements of the options identified in Steps 8 and 9, in addition to factors outside the scope of this process.

5.9 Step 11 - Implement Preferred Option

Under Step 11 the preferred option is implemented and includes the following activities:

a) If a decision is made to use Option 1, then Step 11 is where the data collection would occur.

b) If a decision is made to use Option 2, the concentration limits to which the site is cleaned up are based on the scenarios and consequence analysis simulations conducted in the previous steps. Once the remedial action is performed, additional data are collected to verify that the remediation reduced the extent and amount of residual contamination to the targeted levels (through a Final Status Survey). If the Final Status Survey demonstrates that contamination and potential exposure have been reduced to acceptable levels, then the site proceeds to the stage of either restricted or unrestricted release.

c) If a decision is made to conduct both Options 1 and 2, remediation would be performed in combination with data collection for the purposes of reducing the estimated dose.

To support a future request for license termination, any site survey results, parameter data, or laboratory tests should be carefully documented.

5.10 Step 12 - Revise Model Assumptions, Parameter Values, and Pathways

Once the preferred option has been implemented, the model assumptions, parameter values, and pathways (as appropriate) would be revised. Depending on the results of data collection, the new data can be used to eliminate pathways, refute certain model assumptions, justify new parameter values or refine parameter distributions, or to reduce the estimated extent and amount of residual contamination.

If remediation is performed on portions of the site or to levels that are less than complete, then new parameter values, refined parameter distributions, and/or new model assumptions should be defined to reduce the estimated extent and amount of residual contamination.

5.12 Reiteration of Step 4:

As appropriate, revised scenarios, pathways, parameters, and source terms would be used in a second iteration of the dose assessment. Depending on the application, the licensee could leave the original default model assumptions and pathways unchanged, or in other more complicated situations modify assumptions and pathways or apply different models.

5.13 Reiteration of Step 5:

The revised dose assessment would be evaluated to determine if the calculated dose meets the requirements in 10 CFR 20, Subpart E. The licensee would find either that:

a) The result in Step 5 is that the calculated dose is less than or equal to the 25 mrem/y dose criterion of 10 CFR 20.1402. **If this is the case, proceed to Step 6**

b) The result in Step 5 is that the calculated dose is greater than the 25 mrem/y dose criterion of 10 CFR 20.1402. If this is the case, it means that the contamination at the site is such that the licensee would need to consider additional options to terminate the license, or possibly consider further remediation or restricting site use. Thus, if this result is found, the licensee should **proceed to Step 8 again**. The licensee is encouraged to actively work with the NRC during this step to evaluate the appropriateness and adequacy of the analyses before moving on and expending resources on follow on steps.

5.14 Step 6 - ALARA Requirements

If the result in Step 5 is that the 25 mrem/y criterion has been met, the licensee can proceed to satisfy ALARA requirements, if not already addressed. ALARA actions at this step should be based on Section 4 of DG-4006. The licensee is encouraged to actively work with the NRC to discuss alternative ALARA actions under this step prior to implementing any actions.

5.15 Step 7 - License Termination and Site Release

For this step of the process refer to DG-4006 and NUREG-1575 for guidance on performing the final status survey and other steps necessary prior to license termination.

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APPENDICES

Appendix A - Scenarios, Pathways, and Critical Groups

This appendix provides information for defining the scenarios, pathways, and critical groups that are important for the site dose assessment. This allows for identification of

a) potential human activities on or near the site which can result in exposure (scenarios)

b) migration and exposure pathways of the radionuclides (pathways)

c) critical receptors (the critical group).

Scenarios are defined as reasonable and plausible sets of human activities and of future uses of the site. As such, scenarios provide a description of future land uses, human activities and behavior of the natural system.

With an understanding of the potential human activities and the physical system, one can then develop conceptual models of the site (See main text, Figure 1, Step 3, and Appendix B). Those conceptual models are translated into mathematical models and implemented in (and solved by) corresponding analytical or numerical models and computer codes. The objective is to calculate a dose (main text, Figure 1, Step 4) which is then compared with dose criteria (main text, Figure 1, Step 5) to assess whether the site complies with requirements.

The definition of scenarios and identification of pathways and the dose assessment based on that definition, can be generic or site specific. A critical group that is appropriate for the site should be used. Licensees might:

(a) For simple situations, use screening scenarios, screening groups, and pathway parameters and described in this NUREG (note that even licensees with significant contamination may use this approach if they choose),

(b) For sites with little contamination, use the default screening scenarios but develop more site-specific parameters and/or pathway analyses, or

(c) For sites with significant amounts of contamination, it may be necessary to define and use site specific scenarios and site specific critical groups for use with site specific pathway analysis and parameters.

Section A.1 describes the rationale for using the generic approach. Section A.2 describes the method the licensee would use in developing site specific scenarios, critical groups, and pathways. Section A.3 provides background information regarding the critical group, including its regulatory basis. Description of the methods for changing parameters is contained in Appendix C.

A.1 Generic Scenarios, Critical Groups, and Pathways

Scenario descriptions acceptable to NRC for use in generic screening are developed and contained in NUREG/CR-5512, Volume 1 [Kennedy and Strenge, 1992]. NUREG/CR-5512 and NUREG-1549 provide the rationale for applicability of the generic scenarios, critical groups, and pathways at a site, the rationale and assumptions for scenarios and pathways included (and excluded), the conceptual modeling approaches, and the bases for revising parameters and pathways based on site specific information. There are two critical groups used for screening (referred to here as “screening groups” based on the default scenarios of NUREG/CR-5512:

1) Building occupant for reuse of structures. This scenario accounts for exposure to fixed and removable thin layer or surface contamination sources within a structure. The building occupant is defined as a person who works in a commercial building following license termination. The pathways that apply to the building occupant include:

    a) external exposure to penetrating radiation from surface sources,

    b) inhalation of resuspended surface contamination,

    c) inadvertent ingestion of surface contamination.

    An example of the models used in DandD to mathematically represent these pathways are described in Appendix B. The parameters used in DandD to describe these pathways are presented in Appendix C and Attachment 1. It is possible to modify the parameters for the building occupant based on information about the parameters presented in Attachment 1.

2) Resident farmer for contaminated soil sites, This scenario accounts for potential exposure to residual radioactive contamination in soil. For this scenario, the soil contamination is assumed to be contained in a surface-layer. The resident farmer is defined as a person who lives on the site following license termination, grows some portion of their diet on the site, and drinks water from an on-site well. The pathways that apply to the resident farmer include:

    a) external exposure to penetrating radiation from volume soil sources while outdoors

    b) external exposure to penetrating radiation from volume soil sources while indoors

    c) inhalation exposure to resuspended soil while outdoors

    d) inhalation exposure to resuspended soil while indoors

    e) inhalation exposure to resuspended surface sources of soil tracked indoors

    f) direct ingestion of soil

    g) inadvertent ingestion of soil tracked indoors

    h) ingestion of drinking water from a groundwater source

    I) ingestion of plant products grown in contaminated soil

    j) ingestion of plant products irrigated with contaminated groundwater

    k) ingestion of animal products grown onsite (i.e., after animals ingest contaminated drinking water, plant products, and soil)

l) ingestion of fish from a contaminated surface-water source

The models used in DandD to mathematically represent these pathways are described in Appendix B. The parameters used in DandD to describe these pathways are presented in Appendix C and Attachment 1. It is possible to modify the parameters for the residential scenario based on the information presented in Appendix C.

A.2 Site Specific Scenarios, Critical Groups, and Pathways

Site specific scenarios, critical groups, and pathways based on site-specific information can be developed. This information could describe a critical group, referred to here as a "site-specific critical group," which is different from the screening group. Use of a site specific critical group would occur in cases where, for example:

a) major pathways (e.g., the groundwater pathway, or agricultural pathways) associated with the screening group could be eliminated, either because of physical reasons or site use reasons,

b) there was a specific sensitive group on the site,

c) restricted use was proposed for a site

Modifying scenarios and developing site-specific critical groups requires information regarding plausible uses of the site and demographic information. Such information might include considerations of the prevailing (and future) uses of the land and site specific issues such as historical and planned future land use, and physical characteristics that constrain site use. It may be necessary to evaluate several potential critical groups, based on different combinations of site-specific scenarios developed from expected pathways and demographics, to determine the group receiving the highest exposure. It is especially important to evaluate the homogeneity of specific groups to determine if what appears to be one group is actually multiple groups.

For restricted release, similar considerations apply. However, now the nature of the critical group is likely to changes due to site restrictions and institutional controls which can restrict certain kinds of activities or land or water uses. The detailed definition of the scenarios considered for restricted release need to include the impact of the control provisions on the location and behavior of the average member of the appropriate critical group.

In developing site specific scenarios, critical groups, and pathways, the following should be evaluated:

a) Whether the generic scenarios of NUREG/CR-5512 are applicable to its site and, if so, for each scenario, whether major exposure pathways can be modified or eliminated from further consideration based on site-specific conditions (pathways can be added or eliminated, as appropriate, using site-specific data and it is possible that different scenarios and associated pathways may be necessary for complex site specific analyses beyond those developed for screening).

   This evaluation should include adequate justification, based on site specific data, for eliminating scenarios and/or pathways from the analysis.

As examples, for a site in a predominantly urban or industrial location or for a site in a particularly rocky environment, a licensee may want to defend not using the screening group in favor of a scenario more representative of prevailing (and future) uses of the land. In this case the historical and planned future land use or the physical characteristics of the site may be such as to preclude the generic resident farmer scenario of Appendix A.1. Such a demonstration would be enhanced in cases where the radionuclides at the site were relatively short-lived and the time period over which such a situation might need to last were therefore also relatively short. This approach could be appropriate for the situations noted here based on their characteristics (and therefore be an unrestricted use of the site), and would not require the establishment of institutional controls to restrict site use under 10 CFR 20.1403.

Similarly, other aspects of the site and critical groups that might be exposed could be considered, including factors related to the existence of plumbing systems, floor drains, and embedded piping, ventilation ducts, building external surfaces, and embedded contamination in surfaces that will remain after license termination.

Table A.1 provides a possible set of scenarios that licensees may consider for use in site specific dose assessments.

b) An analysis of exposure pathways should begin with at least the pathways prescribed by NUREG/CR-5512 (and as listed for the building occupant and resident farmer scenarios in Appendix A.1 of this NUREG). After considering those pathways, a more thorough pathway analysis may be needed. The objective of this approach (i.e., proceeding from generic to more site specific pathways) is to focus resources on the pathways, and models associated with those pathways, that have the highest likelihood of significant exposures to the critical group. Applying this pathway analysis process results in a set of the dominant pathways for the site-specific scenarios (see Table A.1) that could be further revised using site-specific conditions. Licensees will need to document their pathway analyses and provide justification for the elimination of pathways from dose assessments.

Table A.1 Potential Scenarios for use in Dose Assessments
These scenarios are applicable for unrestricted release of the site and for analyzing restricted release sites assuming institutional controls fail. The NUREG/CR-5512 scenarios may be based on the screening group, but the scenario definition and pathways may be changed due to site specific considerations (e.g. no drinking water, no pond, etc.). Some of these scenarios are also appropriate for restricted release of the site. In addition, they may be considered for unrestricted sites for which geography or realistic future uses of the site would preclude certain uses (such as agriculture).
C Building occupancy (Generic screening - NUREG/CR-5512 based). C Residential farmer (Generic screening - NUREG/CR-5512 based). C Urban construction (contaminated soil, no suburban or agricultural uses).This scenario is meant for small urban sites cleared of all original buildings; only contaminated land and/or buried waste remains. C Residential (a more restricted subset of the residential farmer scenario, for those urban or suburban sites where farming is not a realistic projected future use of the site). C Recreational (where the site is preserved for recreational uses only). C Hybrid industrial building occupancy (adds contaminated soil, building may or may not be contaminated). C Drinking water (no on-site use of groundwater; off-site impacts from the contaminated plume).

A brief summary of the NRC-recommended pathway analysis process is as follows:

1) Compile a list of exposure pathways applicable to any type of contaminated site (this list is developed in NUREG/CR-5512 and summarized in Appendix C.1 of this NUREG)

2) Categorize the general types of contamination at the site (e.g. sediment or soil, deposits in buildings and equipment, surface contamination, surface waters, groundwater, industrial products such as slag).

3) Screen out pathways for each contaminant type that do not apply to the site.

4) Identify the physical processes pertinent to the pathways for the site.

5) Separate the list of exposure pathways into unique pairs of exposure media (e.g. source to groundwater, groundwater to surface water, etc.). Determine the physical processes that are relevant for each exposure media pair and combine the processes with the pathway links.

6) Reassemble exposure pathways for each source type, using the exposure media pairs as building blocks, thus associating all the physical processes identified with the individual pairs with the complete pathway.

A.3 Background Information Related to “Critical Group”

This section provides background information on the critical group which a licensee can use in understanding the terms “critical group,” “screening group”, and “site specific critical group.”

A.3.1 The requirements in Subpart E for Critical Groups

The dose calculated from residual radioactivity at a decommissioned site is dependent upon how the receptor and the physical characteristics of the site are defined. With regard to the receptor, Subpart E contains the following specific requirements:

1) 20.1402 states that the criterion for unrestricted release is 25 mrem/y to the average member of the critical group;

2) 20.1403, in setting criteria for restricted release, addresses two separate critical groups and hence a licensee would have to evaluate two separate critical groups for restricted use as follows:

    a) 20.1403(b) states that the criterion for restricted release is 25 mrem/y to the average member of the critical group with institutional controls in place (per 20.1403(b), because site restrictions limiting or eliminating certain kinds of activities are highly site specific, the nature of the critical group is also highly site-specific (see Section C.2)

    b) 20.1403(e) states that, if the institutional controls are no longer in effect, the criterion is that the dose to the average member of the critical group is less than either 100 mrem (1 mSv) per year or 500 mrem (5 mSv) per year: A second critical group would have to evaluated based on consideration of the restrictions failing and unrestricted use occurring. The considerations as to the critical group for this situation would be similar as those noted above for 20.1402.

The terms “critical group” and “average member” are defined and discussed in the regulations in the following way:

a) The critical group for decommissioning is defined in 10 CFR 20.1003 as “the group of individuals reasonably expected to receive the greatest exposure to residual radioactivity for any applicable set of circumstances.” NUREG/CR-5512, Volume 1, similarly describes the Critical Group as an individual or relatively homogeneous group of individuals expected to receive the highest exposure within the assumptions of the particular scenario.

b) The average member of the Critical Group is an individual who in turn is assumed to represent the most likely exposure situation based on prudently conservative exposure assumptions and parameter values within the model calculations.

<u>A.3.2 Background information on Critical Groups</u>

ICRP 46 (ICRP 1985) contains a detailed and useful definition of the critical group that could be applied to decommissioning sites:

> “The critical group should be representative of those individuals in the population expected to receive the highest dose equivalent, and should be relatively homogeneous

with respect to the location, habits and metabolic characteristics that affect the doses received. It may comprise existing persons, or a future group of persons who will be exposed at a higher level than the general population. When an actual group cannot be defined, a hypothetical group or representative individual should be considered who, due to location and time, would receive the greatest dose. The habits and characteristics of the group should be based upon present knowledge using cautious, but reasonable, assumptions." {Paragraph 46}

ICRP 43 - Principles of Monitoring for the Protection of the Population, 1984

"...The [ICRP] Commission believes that it will be reasonable to apply the appropriate dose-equivalent limit for individual members of the public to the mean dose equivalent in the critical group. It is recognized that, because of the innate variability within an apparently homogeneous group, some members of the critical group will in fact receive dose equivalents somewhat higher than the mean. However, because of the maximizing assumptions normally used, the dose equivalent actually received will usually be lower than the estimated dose equivalent." {Paragraph 15}

"One of the major aspects in the choice is the size of the critical group. It is clearly stated by the [ICRP] Commission (see [Paragraph 15]) that the dose-equivalent limits are intended to apply to the mean dose equivalent in a reasonably homogeneous group. In an extreme case it may be convenient to define the critical group in terms of a single hypothetical individual, for example when dealing with conditions well in the future which cannot be characterized in detail. Usually, however, the critical group would not consist of one individual nor would it be very large for then homogeneity would be lost. The size of the critical group will usually be up to a few tens of persons...This guidance on size has certain implications; for example, in habit surveys it is not necessary to search for the most exposed individual within a critical group in order to base controls on that person. The results of a habit survey at a particular point in time should be regarded as an indicator of an underlying distribution and the value adopted for the mean should not be unduly influenced by the discovery of one or two individuals with extreme habits." {Paragraph 67}

"In calculating dose equivalents to critical groups it is important to select appropriate mean values for factors such as food consumption rates or occupancy parameters. However, metabolic parameters should be chosen to be typical of the age-group...in the normal population rather than extreme values." {Paragraph 68}

Similar definitions can be found in IAEA Safety Series No. 57 (IAEA 1995) and several NRC documents related to low and high level waste.

Appendix B Dose Models

System Conceptualization (see main text, Figure 1, Step 3) includes conceptual and mathematical model development and assessment of parameters. The system conceptualization represents the process of systematically evaluating the level of uncertainty associated with a specific site and the quantification of that uncertainty. In this methodology, the four steps of scenario definition, pathway identification, model development, and parameter assessment are treated as a hierarchy, moving from the former to the latter. This appendix discusses development of models for calculating dose.

The dose models are used to perform dose assessments (see main text, Figure 1, Step 4) using the mathematical representations of the conceptual models (codified in DandD or equivalent software). The dose assessment involves the execution of the numerical model(s) that implement the mathematical equations and will provide the basis for assessing compliance with the individual dose criteria.

As is the case for the scenarios and pathways (see Appendix A), models used in dose assessments can be either generic or site-specific. The following sections describe the process which should be used in selecting models for dose assessment at a site.

B.1 Generic models

B.1.1 Mathematical models

As with scenarios and pathways (see Appendix A), conceptual and mathematical models have been defined for the NUREG/CR-5512 methodology and these models (codified in the DandD software) are acceptable for making generic dose assessments. DandD can be used for dose assessment based on an evaluation of whether or not the NUREG/CR- 5512 models are appropriate for the site being evaluated given the following assumptions made in developing the 5512 models and any change in the model assumptions or scenarios for site-specific analyses:

a) Initial radioactivity (at the time of the initial event or at decommissioning) is contained in the top layer (building surface or soil) and the remainder of the unsaturated zone and groundwater are initially free of contamination

b) The activity in the aquifer is diluted by the minimum of either the volume of water infiltrating through the garden area or the volume of water required to meet the domestic needs of the resident.

c) The receptor is assumed to be located at the source.

B.1.2 Selection of Codes

As noted in NUREG-0856 [Silling, 1983], it is important that codes and databases used in the analysis be properly verified and documented according to a rigorous quality assurance (QA)/ quality control (QC) program.

B.2 Site Specific Models

Site specific models might be preferable if the generic models are not adequate for the site, a more realistic or representative model is required, or because a model different from the generic model developed in NUREG/CR-5512 (and codified in DandD) is more appropriate.

If site-specific models are developed (either through changes to the default parameter values, model assumptions or development of new models), the selected model and associated parameters should be justified.

B.2.1 Site specific Model development

B.2.1.1 Conceptual models

If site-specific models and parameters are used, a justification for the use of the conceptual model should be provided. The conceptual model includes the set of assumptions of how the described system can be simplified for representation with a mathematical model. The simplification of the physical system into a mathematical model requires the analyst to make consistent, defensible assumptions. An adequate defense for each assumption should be provided.

It is likely that there is uncertainty in the conceptual model and more than one possible interpretation of the system can be justified based on the existing information. It may be necessary to address this uncertainty by developing multiple alternative models of the system and proceeding forward through the framework with all the conceptual models that are consistent with available data.

B.2.1.2 Mathematical models

The conceptual model describes how the contaminants move from the source to the receptor. The mathematical models, and the numerical links between those models, are the equations that implement the conceptual model. Each transport and exposure pathway may require a separate conceptual and mathematical model.

The source model generally describes a boundary condition for a contaminant transport model or the concentration for a model of direct exposure to the source. The pathway models provide an estimate of the amount and distribution (concentration) of the contaminant. The exposure model translates the concentration into an amount of energy (or mass) absorbed or ingested as a function of human behaviors. Finally, the exposure is translated into a dose based on the ICRP 26, 30 and 48 models (a regulatory based requirement for TEDE).

B.2.1.3 Source models

Source models are developed based on the following:

a) Possible mathematical representations of the source include constant surface or volumetric concentration, specified mass flux and time variant concentration or flux boundary conditions. If the NUREG/CR-5512 models are used, then the source is represented with an average initial activity density or concentration (the total amount of activity for each isotope per unit area on a building surface or per unit volume in the upper soil layer) which changes over time due to radioactive decay (depletion due to decay, production from decay of the parent) and transport away from the source area (by leaching from soil or resuspension from the building surface). The leaching and resuspension processes are modeled as fractional releases of the total source mass.

b) In the analysis of the dose due to contamination of building surfaces, the DandD models estimate the dose due to inhalation as a function of the concentration in air. A resuspension factor is used to estimate the concentration in air as a function of the concentration on the surface. The licensee may choose to propose a site or contamination specific resuspension factor.

c) In the DandD models, soil contamination is divided into two components: sorbed mass and leached mass. All the mass that is not retarded by sorption is leached from the source and transported to the groundwater system during the first simulated year. In reality, the amount of mass that is transported to the groundwater system in the first year will be a function of the infiltration rate and the contaminant solubility which is a function of the geochemical conditions and the physical and chemical nature of the source of contamination. Laboratory experiments or geochemical modeling can be conducted to support a more realistic representation of the source. It is recommended that the identification and selection of options for site specific analyses be weighed in terms of the potential benefit and costs (Steps 8-10).

B.2.1.4 Transport models

The potential transport mechanisms for moving the contaminant from the source to the receptor include mechanical disturbances by the receptor (direct exposure to the source) and diffusive and advective transport via air (wind), surface water and groundwater (unsaturated and saturated). The models for these processes can be very complex (e.g. three-dimensional, transient, advection-dispersion equations for flow through heterogeneous media with source and sink terms) or simplified empirical models (e.g., transfer functions like resuspension factor). The level of complexity of the model that can be justified depends on the nature of the simplifying assumptions (conservative, reasonably conservative) and the information available to support the model (a complex model may be more realistic, but the data necessary to support the development of parameter values may not be available or obtainable). Multiple, simple alternative models may be necessary to evaluate the system when the relative conservatism cannot be determined *a priori*.

B.2.1.5 Exposure models

The conceptual model describes the human behaviors (scenario and pathways) that lead to, and control the amount of, exposure. It includes the consumption rates (e.g. rates of respiration times the volume of intake per inhalation) for each media and the time and duration of exposure.

B.2.1.6 Dose models

The dose criterion in 10 CFR 20.1402 is based on the TEDE concept. The TEDE is to be calculated based on the definition of TEDE in Subpart E.

Once the numerical models are developed, a demonstration is prepared addressing how all the mathematical models are linked. The model parameters are defined in this process.

B.2.2 Use of deterministic or probabilistic approach for site specific models

In preparing site specific models, the analyses can be conducted deterministically or probabilistically. A deterministic estimate of dose should be demonstrably conservative, whereas a probabilistic approach quantitatively depicts system performance as a distribution of potential outcomes based on uncertainty and variation in parameters and possibly models.   Regardless of the type of analyses chosen, justification is needed to demonstrate that the analyses provide sufficient information for the decision. These two approaches are:

a) Option 1 - Deterministic analysis

Deterministic analysis involves the calculation of a single value of the dose using single values for input parameter values. Single estimates of dose often can be conducted easily, but the selection of appropriate models and parameter values may be difficult. When performance is measured against a single estimate, uncertainty is addressed by providing reasonable assurance that this estimate conservatively bounds actual performance. Given the uncertainties inherent in these dose assessments, it is expected that deterministic analyses will use simple modeling approaches, assumptions, and parameter values that readily can be demonstrated as being conservative (i.e., produce simulated doses that are consistently greater than real doses).

b) Option 2 - Probabilistic analysis

Probabilistic approaches encompass a wide range of analysis techniques and methods. For this report, the probabilistic approach refers to the use of a formal, systematic uncertainty analysis to quantify the uncertainty in performance estimates because of uncertainty and variability in the parameters. Probabilistic analyses under this framework may involve the analysis of individual scenarios, each with multiple possible pathways, and possibly with alternative models for certain pathways. Parameter uncertainty would likely be quantified and propagated through the dose assessment models.   Parameter uncertainty is often evaluated using a Monte Carlo analysis where the input variables representing parameter uncertainty and the output of model(s) are in the form of distribution functions [see Davis, *et al*., 1990]. An output distribution is produced by evaluating the performance many times, using sets of input values based on random and Latin Hypercube Sampling (LHS) [Iman and Shortencarier, 1984]. The specification of the parameter distribution should reflect the level of knowledge about the parameter or “degree of belief” rather than concentrate on rigorous statistical efforts to determine distributions. As a result, this approach does not require extreme amounts of site specific data to specify the parameter distributions.

Probabilistic analyses may be used to support compliance determination based on a deterministic value taken from the resulting distribution of output or compliance determination based on a comparison of the entire output distribution to the performance objective.

B.2 Selection of site specific codes

The justification for the use of a site-specific code should be based on a demonstration that the mathematical representation of a given fate or transport process as implemented within the selected code is not inconsistent with the set of assumptions defined in Appendix A and a verification that the mathematical representation as implemented in the code is correct.

If enough uncertainty exists such that alternative conceptual models exist (i.e., alternative sets of assumptions are proposed), then it will probably be necessary to select alternative codes or alternative configurations of the same code and conduct the analyses with each of these. It may be necessary to provide results from all the conceptual models. Often times, it will not be possible to deduce, until after the quantitative dose assessment, which model yields the highest doses.

The options for code selection for a site specific analysis and the defense needed under each option are:

a) Use DandD with alternative parameter values and modified/eliminated pathways

To use DandD but modify or eliminate the generic pathways developed in NUREG/CR-5512 (and listed in Appendix A.1), the modifications to the DandD pathways for the specific site and modified site representation in DandD will need to be justified.

b) Licensee-selected code

As described above, the use of DandD (i.e., NUREG/CR-5512) models may not be appropriate for a specific site or another code may just be preferred. In this case, the licensee should:

(1) demonstrate that the set of implicit assumptions associated with the code that has been chosen are consistent with the site specific scenario and pathways (see Appendix A) and the site conceptual model(s) (see Section B.1 above).

(2) if the code has default parameter values built in, the appropriateness of those parameter values for the specific site should be justified.

(3) justify the model assumptions implied by the use of the code.

(4) provide to the NRC, if requested, a copy of the code executable, user's manual for the code, an electronic copy of the input file, and an electronic copy of the output file.

As noted in NUREG-0856 [Silling, 1983], it is important that codes and databases used in the analysis be properly verified and documented according to a rigorous quality assurance (QA)/ quality control (QC) program.

Appendix C: Parameter Descriptions and Information for Changing Parameters

C.1 Parameter Descriptions and Information for Changing Parameters in DandD

Tables C-1 through C-6 list parameters to be evaluated if model parameters are changed from the defaults. Each of the tables indicates a definition of the parameter and also considerations involved in modifying the parameter.   More details about the parameter distributions are contained in Attachment 1 to this NUREG.

The evaluation and potential modification of the parameter will be different depending upon whether the parameter is physical, behavioral, or metabolic, and upon whether a deterministic or probabilistic analysis is performed. Note that, for deterministic calculations, parameters that are not modified using regional or site-specific information will be set to the value of the 90th or 5th percentile of their original distribution, as noted in the parameter descriptions below.

Physical parameters are presented in Tables C-1 through C-3 as follows:

Table C-1	Physical Parameters That Need to be Evaluated if Water Pathway Parameters are changed
Table C-2:	Physical parameters Which Should Be Evaluated If Diet or Ingestion Parameters Are Changed
Table C-3:	Physical Parameters Which do not need to Be Changed If Other Parameters Are Changed

These parameters were originally defined to encompass the variability expected across all licensees in all regions of the country. These parameters usually depend on physical features of the site that may vary based on local geological and meteorological characteristics. Modifications to these parameters can be based on the development of a narrower distribution that better represents site-specific features or location, or selection of a more realistic but still bounding deterministic value from within the distribution developed for the default analysis. Some physical parameters are surrogates for multiple processes within the model and are not correlated to specific physical processes that will be significantly different from site to site, or development of site-specific information may require complex or expensive specialized analyses that would not normally be justified for a decommissioning action. These parameters are in a separate table to clarify which parameters need to be changed and which parameters may be changed whenever parameter modification is chosen as the preferred option.

Behavioral parameters represent the average member of the screening group and are contained in Tables C-4 and C-5 as follows. :

Table C-4	Behavioral parameters that need to be evaluated for site specific critical groups
Table C-5	Behavioral parameters that may be changed to account for modifications to screening group assumptions

These parameters are based on the variability between individuals in the screening group. The metabolic parameters are contained in Table C-6, which also includes discussion of dependent parameters, represent the physiological variability between individuals in the screening group. These parameters were defined by development of distributions representing the screening group, then selecting the mean of the distribution to represent the average member of the group for the deterministic value to be used in the default modeling. These mean values and underlying distributions are not expected to change based on site-specific information unless the licensee proposes a site-specific critical group which is different from the screening group. Therefore, a licensee who chooses the option of modifying parameters will generally not need to modify the behavioral and metabolic parameters.

However, a critical group may be defined for restricted use scenarios, or to account for physical features or legal requirements which cause the screening group to not be representative of the current and future use of the site. If the screening group definition is modified or replaced with a site-specific critical group, all behavioral and metabolic parameters related to the critical group should be evaluated and modified as appropriate.

Table C-1: Parameters That Need to be Evaluated if Water Pathway Parameters are changed - Physical

Parameter	Description	Discussion
H_2	Thickness of the unsaturated zone	Definition: The thickness of the unsaturated zone is used in determining radionuclide leach rates from the unsaturated zone to the saturated zone. The default distribution was developed from area-weighted data from observation wells across the U.S. Information on H_2 (also called water table depth) is readily available from state or city governments and the USGS. Site Specific parameters: Because data are easily available and because it is not possible, *a priori*, to determine whether a thick or thin unsaturated zone is more conservative, licensees using deterministic modeling should use the best estimate of the minimum value for their site.
I, f_1, f_2	Infiltration rate & saturation ratios	Definition: Infiltration rate is measured as the volume of water per unit area per unit time that percolates deeply beneath the root zone and becomes infiltration. The saturation ratio is the volume of water relative to the volume of the pore space, and also the ratio of the moisture content to the porosity. Both these parameters will vary based on regional climate characteristics and site soil texture. A full discussion of these parameters and their derivation, as well as possible information sources for site-specific values, is contained in Attachment 1. Site specific parameters: Because data are easily available, and because it is not possible, *a priori*, to determine whether high or low values are more conservative, licensees using deterministic modeling should use the best estimate of the median value for their site.

Table C-1: Parameters That Need to be Evaluated if Water Pathway Parameters are changed - Physical		
Parameter	Description	Discussion
IR	Irrigation water application rate	<u>Definition:</u> This parameter represents the annual average quantity of groundwater used to irrigate on site agricultural products. It is used, along with the area of land cultivated (A_r) to calculate the volume of water removed from the aquifer per year for irrigation. <u>Site specific parameters:</u> Licensees may propose changes to this parameter based on regional precipitation and regional soil moisture levels and other soil properties, and data that support alternative irrigation rates for certain forage crops or edible foods that may be supported due to prevailing dietary patterns or land use patterns. Because it is not possible, *a priori*, to determine whether high or low values are more conservative, licensees using deterministic modeling should use the best estimate of the median value for their site, based on a multi-year state-specific annual average irrigation rate (attached parameter description report contains such data for twenty-seven states).
n_1, n_2, D_1, D_2, P_s	Porosities, soil bulk densities, and soil areal density of the surface plow layer	<u>Definition:</u> Porosity is a measure of the relative pore volume in the soil and is the ratio of the volume of the voids to the total volume. Soil bulk density relates the mass of dried soil to its total volume (solids and pores together). Soil areal density of the surface plow layer is a measure of the mass of soil per square meter in the surface layer, with an assumed depth of 15 cm for the DandD model. Porosity varies with soil texture, and distributions based on the 12 Soil Conservation Service textural classifications are listed in the attached parameter descriptions. Bulk density can be defined as functionally related to porosity: Bulk density = (1 - porosity)*2.65. Soil areal density is calculated as a conversion of units from bulk density plus the 15 cm depth assumption: Areal density = 150*bulk density or Areal density = 397.5*(1 - porosity). <u>Site specific parameters:</u> Because it is not possible, *a priori*, to determine whether high or low values are more conservative, licensees using deterministic modeling should use the best estimate of the median value for their site, based on the site-specific soil texture.

Table C-2: Parameters Which Should Be Evaluated If Diet or Ingestion Parameters Are Changed - Physical		
Parameter	Description	Discussion
    Q_f Q_g Q_h Q_w	Animal feed intake rates for forage grain hay water	<u>Definition:</u> These parameters represent the average daily quantities of on-site produced foods and on-site well water consumed by livestock. Default values were developed based on the assumption that the total annual diet for the animals is derived from on-site contaminated feed and water from the on-site well. <u>Site Specific parameters</u> Licensees may propose parameter modifications based on limitations on the types or quantities of feed that can be raised on the site and the existence and quality of the on-site well. Intake rates can be used to directly account for the contaminated fraction of feed and water in the animal diet. [Deterministic calculations should be based on the 90th percentile value of the default or revised distribution]
Y_g	Crop yields (grain)	<u>Definition:</u> This parameter represents the average yield of all grain crops consumed by each of the four food-producing animals evaluated in the model, per unit area of cultivated land at the site. The distribution was based on the production of three main grain crops (corn, sorghum, and oats) in direct proportion to the production across the United States. <u>Site specific parameters</u> Licensees may modify this parameter by limiting the distribution to crop types likely to be grown in the area of their site, as well as incorporating climatic conditions and soil features that may affect production. [Deterministic calculations should be based on the 90th percentile value of the default or revised distribution]
Y_h	Crop yields (stored hay)	<u>Definition</u> This parameter represents the average yield of all hay crops consumed by each of the four food-producing animals evaluated in the model, per unit area of cultivated land at the site. <u>Site specific parameters</u> Licensees may modify this parameter by limiting the distribution to crop types likely to be grown in the area of their site, as well as incorporating climatic conditions and soil features that may affect production. [Deterministic calculations should be based on the 90th percentile value of the default or revised distribution]

Table C-2: Parameters Which Should Be Evaluated If Diet or Ingestion Parameters Are Changed - Physical		
Parameter	Description	Discussion
Y_v	Crop yields (stored vegetables, fruits, & grains)	<u>Definition</u> This parameter represents the amounts of garden produce grown per unit area of cultivated land at the site and is based on the production of all crops in direct proportion to the production across the United States. <u>Site specific parameters</u> Licensees may modify this parameter by limiting the distribution to crop types likely to be grown in the area of their site. [Deterministic calculations should be based on the 90th percentile value of the default or revised distribution]

Table C-3: Parameters Which do not need to Be Changed If Other Parameters Are Changed* - Physical		
Parameter	Description	Discussion
B_{jv}	Vegetation concentration factors for uptake	<u>Definition</u> This parameter is affected by multiple factors that vary non-linearly in time and across locations. <u>Site specific parameters</u> Licensees are not expected to modify the default without specialized site-specific analysis. Licensees may propose different values based on published, peer reviewed data not evaluated in the parameter analysis. However, no further analysis is required by the licensee, and this parameter does not have to be modified if other parameters are changed. [Deterministic calculations should be based on the 90th percentile value of the default or revised distribution]
f_{Ca}	Fraction of carbon in animal products	<u>Site specific parameters</u> Licensees are not expected to modify the default without specialized site-specific analysis. Licensees may propose different values based on published, peer reviewed data not evaluated in the parameter analysis. However, no further analysis is required by the licensee, and this parameter does not have to be modified if other parameters are changed. [Deterministic calculations should be based on the 90th percentile value of the default or revised distribution]
CDO, CDG	Air dust-loading outdoors & gardening	<u>Definition</u> These parameters represent the long-term averages for respirable particulate material in outdoor air. <u>Site specific parameters</u> Licensees may propose alternate values based on site-specific, local climatic conditions which impact dust loading such as wind speed, soil moisture, soil type, topography, and vegetation cover. Table 3.2.2 in the attached parameter description provides additional information. [Deterministic calculations should be based on the 90th percentile value of the default or revised distribution]

Table C-3: Parameters Which do not need to Be Changed If Other Parameters Are Changed* - Physical		
Parameter	Description	Discussion
f_{Ch}, f_{Cg}, f_{Cf}	Fraction of carbon in forage, stored grain, and stored hay	Site specific parameters Licensees are not expected to modify the default without specialized site-specific analysis. Licensees may propose different values based on published, peer reviewed data not evaluated in the parameter analysis. However, no further analysis is required by the licensee, and this parameter does not have to be modified if other parameters are changed. The one exception is f_{Cf} because of the different forage crops that grow in different regions throughout the U.S. Regional data may support a different value based on specific forage crop growth. [Deterministic calculations should be based on the 90th percentile value of the default or revised distribution]
KD_{ki}	Partition coefficients	Definition Partition coefficients define the ratio between radionuclide solid concentrations (radionuclide quantity adsorbed on the soil/rock particles) and radionuclide liquid concentrations (radionuclide quantity dissolved in the soil/rock pore water) under equilibrium conditions. These coefficients are used to calculate radionuclide retardation and define the transport velocities in the soil layer and unsaturated zone. Transport velocities determine the radionuclide leaching rates. Partition coefficients noticeably affect doses because they significantly influence the mass transfer rates between soil, unsaturated zone, and aquifer and the subsequent concentrations in soil, drinking water, and water used for agricultural purposes. Radionuclides most sensitive to this parameter tend to be those whose leaching rates are comparable to or greater than the radionuclide radioactive decay constant. Partition coefficients are not correlated to soil type or texture, or other easily measurable site characteristics. Site specific parameters Licensees using deterministic analyses may only replace the default values with values determined from site-specific testing or propose different values based on published, peer reviewed data not evaluated in the parameter analysis. However, no further analysis is required by the licensee, and this parameter does not have to be modified if other parameters are changed. [Deterministic calculations should be based on the 90th or 5th percentile value of the default or revised distribution, depending on the specific radionuclide]

Table C-3: Parameters Which do not need to Be Changed If Other Parameters Are Changed* - Physical		
Parameter	Description	Discussion
RF_r	Resuspension factor	Definition: This parameter represents the ratio of the long-term average respirable contaminant concentration in air to the long-term average floor surface contaminant concentration due to contaminated soil tracked indoors. Site specific parameters Licensees are not expected to modify the default without specialized site-specific analysis. Licensees may propose different values based on published, peer reviewed data not evaluated in the parameter analysis. However, no further analysis is required by the licensee, and this parameter does not have to be modified if other parameters are changed. [Deterministic calculations should be based on the 90th percentile value of the default or revised distribution]
r_v	Interception fraction for vegetation	Definition This parameter represents the average fraction of all deposited contaminates retained on all plants grown for food and animal feed after above-ground irrigation with contaminated groundwater. Site specific parameters Licensees may modify this parameter based on the chemical form of their source term, since different distributions can be supported based on contaminants which are negatively-charged versus positively-charged or insoluble (see attached parameter discussion for details). [Deterministic calculations should be based on the 90th percentile value of the default or revised distribution]

Table C-3: Parameters Which do not need to Be Changed If Other Parameters Are Changed* - Physical		
Parameter	Description	Discussion
V_{dr}	Volume of water removed from the aquifer per year for domestic uses	<u>Definition</u> This parameter represents the annual volume of groundwater removed from the aquifer for domestic uses, including such things as showers, washing, and water used for drinking and cooking. V_{dr} includes the volume of water used for drinking, defined by U_w, and along with the volume of water used for irrigation, establishes the total volume of water in the aquifer. <u>Site specific parameters</u> Since this parameter is influenced by site-specific considerations such as climate, rainfall, and societal restrictions on water use, licensees may propose alternative values for this parameter based on the State-specific values in the attached parameter description document, USGS county data, or other equivalent information. [Deterministic calculations should be based on the 90th percentile value of the default or revised distribution]
   W_f W_g W_h W_v	wet-to-dry conversion factors (forage) (grain) (hay) (vegetables, fruits, & grains)	<u>Definition</u> Wet-to-dry conversion factors correspond to the fraction of dry matter in the particular crop, and varies with the type of crop and the growing conditions. The value for grain, both as used for animal feed and as consumed by humans, is proposed as a constant because there is so little variability between different grain crops. <u>Site specific parameters</u> Conversion factors for fruits, vegetables, and hay/forage crops do vary based on the crop type, and licensees may propose different distributions from the defaults based on site-specific information about the specific crops that could be grown in that area. [Deterministic calculations should be based on the 90th percentile value of the default or revised distribution]

Table C-3: Parameters Which do not need to Be Changed If Other Parameters Are Changed* - Physical		
Parameter	Description	Discussion
Y_f	Crop yields (forage)	<u>Definition</u> This parameter represents the average yield of all forage crops consumed by each of the four food-producing animals evaluated in the model, per unit area of cultivated land at the site. The default distribution is based on the production of hay, as that was determined to be most representative. <u>Site specific parameters</u> Licensees may modify this parameter by limiting the distribution to crop types likely to be grown in the area of their site, as well as incorporating climatic conditions and soil features that may affect production. [Deterministic calculations should be based on the 90th percentile value of the default or revised distribution]
P_d	Floor dust-loading	<u>Definition</u> This parameter represents the long term average mass of contaminated soil per unit area of floor inside the residence. It is used with the resuspension factor to calculate the airborne particulate concentration due to resuspension of soil tracked indoors. <u>Site specific parameters</u> Licensees are not expected to modify the default without specialized site-specific analysis. Licensees may propose different values based on published, peer reviewed data not evaluated in the parameter analysis. However, no further analysis is required by the licensee, and this parameter does not have to be modified if other parameters are changed. [Deterministic calculations should be based on the 90th percentile value of the default or revised distribution]

*Licensees performing probabilistic analyses may use the original distributions developed for the default analyses in their calculations. Licensees using deterministic calculations should use the value of the 90th or 10th percentile of the original distribution or the value recommended in the parameter discussion, as stated in this table.

Table C-4: Parameters That Need to be Evaluated for Site-Specific Critical Groups - Behavioral		
Parameter	Description	Discussion
t_i, t_x, t_g	Exposure periods	Definition During the one year scenario period, the average member of the screening group is assumed to divide their on-site time between indoor, outdoor, and gardening activities. Site specific parameters If the screening group definition is modified or replaced with a site-specific critical group, licensees should re-evaluate this parameter and modify it as appropriate. For example, if the critical group does not engage in agricultural activities, gardening time, alone with ingestion rates of domestic produce, cultivated area, and irrigation rate would be 0. [Deterministic calculations should be based on the mean value of the default distribution]
U_v, U_a, U_f	Ingestion rates of home produced food	Definition These parameters represent ingestion rates of home produced leafy vegetables, other vegetables, fruits, grains (U_v); beef, poultry, milk, eggs (U_a); and fish (U_f). The default ingestion rates represent the diet of the average member of the screening group. These parameters are also important for defining the area of land cultivated parameter A_r. Site specific parameters While the defaults represent values developed from information in national surveys, site-specific values may be different based on regional and meteorological conditions that impact agricultural practices and local dietary habits. U_f can be set to zero if the site does not contain a pond or surface water that could support fish, or if any existing pond or surface water will not be contaminated with residual radioactivity during the 1000 year period following license termination. [Deterministic calculations should be based on the mean value of the default distribution]
U_w	Drinking water ingestion rate	Definition This parameter represents the long-term average daily ingestion of drinking water from an on-site well. Site specific parameters Licensees may modify (reduce or set to zero) this parameter based on site-specific physical factors that affect the existence or quality of the well, or based on information supporting a finding that an on-site well would not become contaminated by residual radioactivity during the 1000 year analysis period. [Deterministic calculations should be based on the mean value of the default distribution unless this pathway is completely eliminated]

Table C-4: Parameters That Need to be Evaluated for Site-Specific Critical Groups - Behavioral		
Parameter	Description	Discussion
SFI	Indoor shielding factor	Definition This parameter represents the attenuation of gamma radiation by structural materials such as walls, floors, and foundations in residential buildings. The model uses a single, constant value for all radionuclides and all structural materials. Site specific parameters Licensees may substitute alternative values for this parameter from Table X.XX based on a shielding factor for the specific energy range for the radionuclides in their source term. It will usually not be acceptable to limit the structural requirements for future structures that may be built on the site unless the licensee proposes restricted release, and such restrictions would not hold for the analysis of dose when controls fail.
GR	Soil ingestion transfer rate	Definition This parameter represents the quantity of soil ingested per day, averaged over the one year duration of the scenario, by inadvertent transfer from hands or other objects that have been in contact with a contaminated surface, such as food, cigarettes, etc. into the mouth. Site specific parameters If the screening group definition is modified or replaced with a site-specific critical group, licensees should re-evaluate this parameter and modify it as appropriate. [Deterministic calculations should be based on the mean value of the default distribution]

Table C-5: Parameters That May be Changed to Account for Modifications to Screening Group Assumptions - Behavioral		
Parameter	Description	Discussion
U_v, U_a, U_f	Ingestion rates of home produced food	Definition These parameters represent ingestion rates of home produced leafy vegetables, other vegetables, fruits, grains (U_v); beef, poultry, milk, eggs (U_a); and fish (U_f). The default ingestion rates represent the diet of the average member of the screening group. These parameters are also important for defining the area of land cultivated parameter A_r. Site specific parameters While the defaults represent values developed from information in national surveys, site-specific values may be different based on regional and meteorological conditions that impact agricultural practices and local dietary habits. U_f can be set to zero if the site does not contain a pond or surface water that could support fish, or if any existing pond or surface water will not be contaminated with residual radioactivity during the 1000 year period following license termination. [Deterministic calculations should be based on the mean value of the default distribution]
U_w	Drinking water ingestion rate	Definition This parameter represents the long-term average daily ingestion of drinking water from an on-site well. Site specific parameters Licensees may modify (reduce or set to zero) this parameter based on site-specific physical factors that affect the existence or quality of the well, or based on information supporting a finding that an on-site well would not become contaminated by residual radioactivity during the 1000 year analysis period. [Deterministic calculations should be based on the mean value of the default distribution unless this pathway is completely eliminated]

C.2 Residential Scenario Dependent Variables & Parameters

Several of the input parameters are derived solely as functions of other model parameters and are treated as dependent variables rather than independent parameters. Other input parameters are functions of parameters that are not input directly to the model, these derivations are independent of the model and continue to be treated as parameters.

Variables

The cultivated area (A_r), volume of irrigation water (V_{irr}), soil areal density of the surface plow layer (PS), fraction of soil that is hydrogen (fhdO16), and surface-soil moisture content (SH) are dependant variables.

A_r represents the minimum cultivated area required to support the individual's domestically produced diet. As defined, A_r is a function of several behavioral and physical parameters, including the diet fraction (DIET)[2], human consumption of on-site produce (U_v) and animal products (U_a), animal consumption of on-site produced feed (Q_{ka}), the fraction of each feed type in the animal's diet (f_{ka}), and the yields for each food or feed category (animal products, feed, vegetables (Y_a, Y_{ka}, Y_v)). The use of this variable in the model and the equations for deriving this area are presented in section 3.2 of Attachment 1. Changes by the licensee to any of these parameter values needs to be accompanied by a corresponding change in A_r. As discussed in section 3.7 of Attachment 1, V_{irr} is calculated as the product of the irrigation rate (IR) and A_r and is already represented as a dependent variable in the DandD code.

For consistency, PS is calculated as a function of the surface soil bulk density (RHO1) and thickness (H1) of the surface-soil layer (Attachment 1, section 5.3, equations 5.3.13 and 5.3.14). Changes by the licensee to either of these parameter values needs to be accompanied by a corresponding change in PS.

Similarly, for consistency, SH and fhdO16 are calculated as a function of the porosity (N1), RHO1 and relative saturation (F1) of the surface-soil layer and any changes to these parameter values needs to be accompanied by a corresponding change in SH and fhdO16.

Parameters

The indoor dust loading factor (CDI) is dependant on the outdoor dust loading factor (CDO) and the ability of the building to prevent the outdoor dust from entering the residence, modeled using a penetration factor (PF). The functional relationship between CDI, CDO and PF is described in Attachment 1, section 5.4. CDO is a parameter in the DandD models, PF is not. If the input value for CDO is revised it needs to be accompanied by a corresponding change in CDI. Information on site-appropriate PF values could be provided to support a change in CDI that is independent of the value for CDO. This feature makes CDI a parameter rather than a variable.

In the parameter analysis, some parameter values are estimated as functions of parameters that are not used directly in the model. These functional relationships fall into 2 categories: conversion from a dry-weight to wet-weight based parameter value and parameter values that are derived as a function of the soil type.

The crop yields for forage and grain are based on data for dry yields that are converted to an estimate of the wet-weight yield using a conversion factor (W_f, W_g). These conversions are discussed in Attachment 1, section 5.5. Similarly, some of the data on animal feed intake rates (Q_k) and vegetation concentration factors (B_{jv}) must be converted to the correct wet or dry weight units for deriving the input parameter value for the DandD models (see Attachment 1, sections

[2] Note: it is recommended that DIET and Xka be removed from the model by setting them equal to 1 and defining the consumption rates based only on the consumption of on-site produced products (DandD will be modified to allow setting DIET to 1).

5.5 and 5.7). If the parameter values are changed based on site-specific data and those data are in the appropriate units for the model input, no conversion will be required.

For the generic parameter analysis, the uncertainty in the physical parameters of the surface soil and unsaturated zones (N1, N2, RHO1 and RHO2) was represented as a function of the soil type (see Attachment 1 section 5.3). The soil type was treated as an uncertain variable in the analysis, but is not a parameter in the DandD models. Infiltration (I) was calculated as a function of the amount of water required for the crops, volume of irrigation water, precipitation and the saturated hydraulic conductivity of the soil layer (also modeled as a function of the soil type). The relative saturation of the soil and unsaturated layers (F1 and F2) were modeled as a function of the soil type (see Attachment 1 section 5.3). The soil and hydrologic parameters could be modified based on site-specific data and/or the results of other models. However, the models used in the parameter analysis may be retained. If they are retained, any change in the soil type needs to be accompanied by corresponding changes in N1, N2, RHO1, RHO2, PS, Ksat, I, F1, F2, SH and fhdO16.

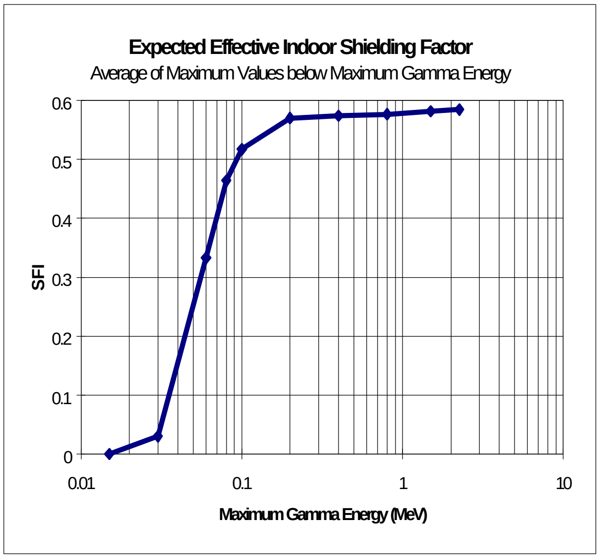
Table C-6: Parameters That May Need to be Evaluated - Other			
Parameter	Type	Description	Discussion
V_{irr}	physical (dependant)	Volume of water removed from the aquifer per year for irrigation use	<u>Definition</u> This parameter represents the volume of water removed from the aquifer for irrigation of all crops grown on site. <u>Site specific parameters</u> It is calculated as a function of the irrigation rate (IR) and the land area under cultivation (A_r) and must be changed if either IR or A_r, or both, are changed.
A_r	physical (dependant)	Area of land cultivated	<u>Definition</u> This parameter represents the area of land that is used for the production of agricultural products for both human and animal consumption. A_r is calculated as a function of the number of food and animal products considered in the diet, the ingestion rates for those products by the individual, and the yields for the food and animal products. <u>Site specific parameters</u> Licensees may propose changes to the food and animal products that compose the on-site resident's diet based on the types of products that can be raised on the site, or physical limits on the site area that can be cultivated. A_r should be recalculated if the types of foods, ingestion rates, or yields are changed. In addition, if the screening group definition is modified or replaced with a site-specific critical group, licensees should re-evaluate this parameter and modify it as appropriate.

Table C-6: Parameters That May Need to be Evaluated - Other			
Parameter	Type	Description	Discussion
CDI	physical (dependant)	Air dust-loading indoors	Definition This parameter represents the process of infiltration of contaminated airborne particles into the house (mass-loading) as the mass of infiltrating particles per unit volume of air. Site specific parameters It is calculated as a function of CDO (air dust-loading outdoors) and PF (penetration factor) and must be changed if either CDO or PF, or both, are changed.
DIET	behavioral (constant)	Fraction of annual diet derived from home-grown foods	Definition This parameter was originally intended to represent the fraction of the average member of the screening group's diet that was derived from food grown on site in the contaminated area. However, it was determined during the parameter analysis that a single diet fraction value for all food types was not representative of the screening group. Therefore, this parameter was set to 1, and the behavior of the screening group, which is expected to produce different fractions of each food product, is represented by the consumption rates U_v, U_a, and U_f. The consumption rates have been redefined to represent the consumption of food derived from on-site production rather than the rate of consumption in general. Site specific parameters Unless this parameter and the consumption rates U_v, U_a, and U_f are re-defined, DIET should not be changed.
SFO	physical (constant)	Outdoor shielding factor	Definition This parameter represents attenuation of the external dose rate during periods outdoors based on shielding by clean cover or other materials. Under normal circumstances associated with unrestricted release, and for evaluation of restricted release following failure of controls, this parameter should not be changed from 1. Site specific parameters This parameter can be changed to account for physical controls under restricted release conditions.

Table C-6: Parameters That May Need to be Evaluated - Other			
Parameter	Type	Description	Discussion
V_r, V_x, V_g	metabolic	Volumetric breathing rates while indoors, outdoors, and gardening	Definition These parameters represent the annual average breathing rate of the average member of the screening group while indoors, outdoors, and gardening. Site specific parameters If the screening group definition is modified or replaced with a site-specific critical group, licensees should re-evaluate this parameter and modify it as appropriate.

The following table lists shielding factors based on the maximum energy of the source term. Licensees may modify the SFI parameter in the model (E[SFI]) based on the maximum energy for their site-specific source term. For example, if the source term maximum energy is less than 0.4 MeV, the default value for SFI can be replaced with 0.574.

Table C.7 Shielding Factors For Various Materials vs. Energy; SFI Replacement Values Based on Maximum Energy						
	Concrete			Wood		
Energy (MeV)	3.5"	5.25"	7.0"	1.0"	Energy (MeV)	E[SFI]
0.015	1.36e-12	2.55e-24	2.55e-24	2.05e-06	0.015	5.13e-07
0.03	8.10e-03	8.10e-03	8.10e-03	9.67e-02	0.03	3.03e-02
0.06	2.41e-01	2.41e-01	2.41e-01	6.08e-01	0.06	3.33e-01
0.08	3.80e-01	3.77e-01	3.77e-01	7.22e-01	0.08	4.64e-01
0.1	4.38e-01	4.32e-01	4.31e-01	7.67e-01	0.1	5.17e-01
0.2	5.07e-01	4.86e-01	4.79e-01	8.07e-01	0.2	5.70e-01
0.4	5.17e-01	4.78e-01	4.62e-01	8.14e-01	0.4	5.74e-01
0.8	4.89e-01	4.25e-01	3.94e-01	8.24e-01	0.8	5.77e-01
1.5	4.91e-01	4.05e-01	3.59e-01	8.45e-01	1.5	5.82e-01
2.25	5.14e-01	4.22e-01	3.69e-01	8.57e-01	2.25	5.85e-01



C.3 Assimilating Existing Data and Information

Data are used to support Step 3 which is development of a conceptual model, and model assumptions and model parameter values. Additional information is needed to support and defend the conceptual model of Step 3 if models other than DandD are used or if site specific parameter values are used. Types of potentially useful information include: processes that utilized the potential contaminants, releases and mitigative actions, hydrologic conditions (soil moisture content, conductivities, depth to groundwater, hydraulic gradients, hydraulic conductivities), soil type and texture, clay content, geochemical conditions (Kd, pH) , atmospheric conditions (annual averages or time and date specific conditions), geology (unconsolidated sediments, fractured rock). Methods for obtaining the necessary additional information to support the site specific parameters and models used are described in Sections 3.1 through 3.4.

MARSSIM (NUREG-1575) chapter 3 discusses the Historical Site Assessment (HSA) process. The first objective of the HSA applies directly to Step 1 of the D&D decision framework. The common objective of Step 1 and the HSA is to identify the potential, likely or known sources of radioactive material and radioactive contamination based on existing information. Section 3.4 and Appendix G of the MARSSIM provide useful guidance on sources of information and Section 3.6 discusses how to identify potentially contaminated media. The other objectives of the HSA (identifying sites that pose a threat to human health and those that do not, assessing the likelihood of contaminant migration, providing useful information for developing and analyzing surveys, and providing an initial classification of the site or specific areas of the site as impacted or non-impacted) are similar to objectives of later steps in this dose assessment decision methodology.

C.3.1 Source data

All pertinent and legitimate *existing* site data and other relevant information that can be used to define characteristics of the residual radioactive (and non-radioactive) contamination at the site is gathered. In defining the residual contamination, all existing information on the amount, location and distribution of all possible contaminants should be evaluated. Where data are unavailable, the amount and distribution of the potential contaminant based on initial inventories (mass balance approach) and the processes involved in generating the original materials (e.g., ore processing, contained source, laboratory analyses) may be estimated. The uncertainty in the extent and amount of residual contamination for each substance will depend on the amount and variability of the data. The uncertainty in the magnitude and distribution of the source should be represented or bounded in the later dose assessment in order to evaluate the worth of collecting additional data about the residual contamination. The uncertainty in the extent and amount of residual contamination can be accounted for in the dose assessment by employing conservative assumptions about the source magnitude and distribution.

As noted in Chapter 3 of the MARSSIM useful sources of information about the potential amount, form and distribution of radioactive contaminants include licenses, site permits, authorization documents, operating records, financial records, site plots, blueprints, photographs, aerial photos and maps. Licenses, permits and authorizations may indicate the quantities of radioactive material, chemical and physical form and types of operations. Operation records may include accounts of intentional and accidental releases of radioactivity (leaks, spills, disposal, storage, routine emissions). These accounts may include estimates of the amount, distribution, and the chemical and physical form of the potential contaminants. Financial records may provide evidence of the amount of material entering and leaving the site. Maps, figures and photos provide information for evaluating the location of potential contamination based on operations.

C.3.2 Hydrogeologic data

Existing data on the geology, surface water and groundwater systems at the site are used to support the conceptual model, defend the use of the DandD models and support the dose assessment model parameter values.

The data used to develop the default parameter values for the 5512 models provides a data base for estimating the uncertainty in the model parameter values (Step 3) and for evaluating how that uncertainty might be reduced given site specific information (Step 8). The hydrologic data in the 5512 parameter analysis include the range in observed unsaturated zone thickness (depth to groundwater), unsaturated zone and soil porosity, saturation ratios (volumetric moisture contents), infiltration rates and volume of the surface water pond.

As noted in the MARSSIM, potentially useful site-specific information includes rainfall; the location of nearby wetlands, intermittent streams, drainages and surface water bodies (rivers, lakes, oceans, coastal tidal waters) relative to the potential sources of contamination; flooding potential; runoff rates; runoff barriers; infiltration rates; soil/subsurface permeabilities; depth to groundwater; and type of groundwater system (karst, fractured rock, porous media; confined; unconfined). Table G.1 in MARSSIM indicates useful sources of hydrogeologic data. In addition to data collected during operations, other agencies that may have useful hydrogeologic information and experts include: the USGS, state geological surveys, state environmental agencies, state departments of transportation, local colleges and universities, local well drillers, local water authorities, local health departments, EPA regional offices, U.S. Army Corps of Engineers, FEMA, US Fish and Wildlife, and national databases (WATSTORE, STORET, GRIDS, National Wetland Inventory Maps).

C.3.3 Chemical data

Existing data on the chemical properties of the potentially contaminated material are used to support the conceptual model and dose assessment model parameter values. The data used to develop the default parameter values for the 5512 models provides a data base for estimating the uncertainty in the distribution coefficients (Step 3) and for evaluating how that uncertainty might be reduced given site specific information (Step 8). This data set can be evaluated in terms of the soil type and site specific information on the soil type can be used to justify reducing the uncertainty in this parameter value.

The Soil Conservation Service is the agency that may have useful information and experts to contact regarding soil type and potentially useful data bases include the National Soil Geographic Database, State Soil Geographic Database, and the Soil Survey Geographic Database. All of the databases are available through EPA's website. Other sources of site specific information include local experts at universities or colleges, state geological surveys and environmental agencies.

C.3.4 Land-Use data

If a site-specific critical group is proposed, land-use data will be used to defend the characteristics of the critical group and model parameter values.

As noted in Appendix G of MARSSIM, local planning and zoning officials, tax assessor, and local university or college geography departments are potential sources of land-use information. The USGS is a source of land use and land cover information and the U.S. Bureau of the Census TIGER Map Service is a source of demographics information.

A key point of this framework is that new site data collection does not take place until Step 12. New data collection is deferred until the data that would make a difference in decision making and are cost effective to collect can be defined through cost/benefit and data-worth activities (Steps 8, 9 and 10). Otherwise, money may be spent on collection of superfluous data.

To start this decision process using the modeling approach described in Volume 1 of NUREG/CR-5512, only information on the nature and extent of the residual contamination is needed. For new sites of any type the same approach is recommended. However, other sites may have evolved further in the process prior to using this approach. In this case, all relevant site data should be included and evaluated. This information may be augmented under later steps where additional data collection activities occur.

Appendix D Area Factors

D.1.0 Area Factors / Elevated Measurement Criteria: Integration of Modeled Risk with Areal Extent of Contamination

Area Factors are used to calculate the maximum concentration, distributed over a specific area, that can remain following decommissioning without requiring additional clean up. They are used to determine the elevated measurement comparison value, as described in NUREG-1505, Chapter 5. Area factors are calculated as a ratio of the dose conversion factor (DCF) based on the default contaminated area to the DCF based on the contaminated area of interest. Since area factors can be applied to any site and are calculated generically, they are based on default parameters developed at a P_{crit} level of 0.05 (Beyeler, et. al, 1996). This level of conservatism is reasonable in the context of developing allowable multiples of the guideline levels for use at sites that will be released from license.

All calculations for area factors in this report were done using the Residential and Building Occupancy Scenarios in DandD version 1.0. The source term in all cases is based on a unit concentration, equivalent to 1 pCi/g in the Residential Scenario and 1 dpm/100 cm^2 in the Building Occupancy Scenario. DandD parameters with links to area are shown on the spreadsheets included in Appendix A, along with proposed modifications based on area of contamination. If the parameter is not listed, no change was made to the Level 1 (L1) default. For the purposes of these calculations, the L1 parameters are set at the P_{crit} = 0.05 level.

D.1.1 General Assumptions in DandD

D.1.1.1 Areal Distribution

A) Residential Scenario

For contamination under a house (the house scenario), it is assumed that the house has an area of about 2,000 square feet (~186 m2). The contamination is assumed to be completely covered by the house until it exceeds a size of 186 m2, at which time the contaminated area exceeding 186 m2 is assumed to be in the cultivated area (garden).

For contamination in a garden (the garden scenario), the contaminated area is assumed to be completely in the garden until the size exceeds the default garden size or a garden size associated with the area needed to support 50% of the individual's diet. Once the contaminated area exceeds the garden size, the excess is assumed to be under the house.

B) Building Occupancy Scenario

For contaminated areas inside buildings, the baseline room is assumed to have a floor area of 4 meters x 4 meters and a ceiling height of 3 meters. External dose is based on the assumption of an infinite flat plane with uniform contamination.

1.1.2 Diet (Residential Scenario Only)

The assumption is made that no more than 50% of a person's diet would be from the contaminated area. Beyond 50%, site-specific adjustments should be made to the parameters because the scenario has been extended beyond the original assumptions made in the construction of the resident farmer scenario. The fraction of the diet is related to area using the L1 baseline area and diet fraction. For contaminated areas other than the default area, the fraction is calculated as the ratio of the default diet fraction to the default area, multiplied by the contaminated area. As explained above, the maximum fraction is limited to 0.5.

$$\textit{Fraction of Diet from Contaminated Area (DIET)} \le$$

$$\frac{\textit{L1 Fraction of Diet}}{\textit{L1 Contaminated Area}} \times \textit{Contaminated Area (A)}, \tag{1}$$

$$\textit{DIET} \le 0.5$$

1.1.3 Time

A) Residential Scenario

This model is structured in such a way that it is not simple to modify the time of exposure to an external source without also affecting the inhalation and ingestion pathways. The time variables used to control time spent indoors and outdoors affect both the time of exposure to external sources, as well as time inhaling resuspended dust and secondary ingestion. Time of exposure is important because it is used as a surrogate for modification of the source geometry. This model currently only supports an infinite flat plane geometry.

The time of exposure to an external source is important for evaluating the effect of contaminated areas smaller or larger than the default area. For example, if it is assumed that a person has an equal probability of being at any location on the site at any time during the analysis period, then the time of exposure to the source can be related to the size of the contaminated area versus the entire site area. If the entire site is contaminated, the person is exposed to the source the entire time they are on the site. If one quarter of the site is contaminated, the person can be assumed to be exposed to the source for one quarter of their time on site. It is important to note that these simplifying assumptions are only valid within the context of this model, which was designed to evaluate distributed, relatively homogeneous low activity sources. It would not be valid, for example, to apply these assumptions or this model to an exposure assessment for a high energy gamma sealed source.

While it is easiest to adjust the external exposure pathway by changing the duration of exposure, other pathways are best adjusted by applying a correction based on the ratio of the contaminated area to the site area while using the default exposure time. In addition, the external exposure pathway is complicated by the fact that it is divided into three components and uses two shielding factors. The components are gardening, outside activities other than gardening, and indoors. Separate shielding factors are applied to indoor and outdoor activities. Since both contamination in the garden and contamination under the house are being evaluated, it is important to be able to change both shielding factors and time spent in each of the three locations. In addition, this allows the time indoors, for example, to be used as a surrogate for time of exposure without impacting the time exposed to resuspended dust from soil tracked indoors.

Given these complications, adjustments to the time of exposure for the external dose pathway are made after the model has first been run with adjustments to all other parameters[3].

The external dose in the residential scenario is calculated by summing the time spent indoors, outdoors on site, and gardening. Additional details regarding the external dose pathway and how it is integrated into the residential scenario can be found in NUREG/CR-5512, Volume 1, page 5.52 to 5.54. The equation used to calculate external dose[4] is as follows:

$$
\begin{aligned}
DEXR_i = & \left[24 \; (t_g/t_{tg}) \; SFO \; C_{si} \sum_{j=1}^{J_i} S\{A_{stj}, \; t_{tg}\} DFER_j \right] \\
& + \left[24 \; (t_x/t_{tr}) \; SFO \; C_{si} \sum_{j=1}^{J_i} S\{A_{stj}, \; t_{tr}\} DFER_j \right] \\
& + \left[24 \; (t_i/t_{tr}) \; SFI \; C_{si} \sum_{j=1}^{J_i} S\{A_{stj}, \; t_{tr}\} DFER_j \right]
\end{aligned} \qquad \textbf{(2)}
$$

where

$DEXR_i$	=	external dose from 1 year of residential scenario exposure to radionuclide I in soils (mrem for a year of residential scenario)
$DFER_j$	=	external dose rate factor for radionuclide j for exposure to contamination uniformly distributed in the top 15 cm of residential soil (mrem/h per pCi/g)
A_{stj}	=	concentration factor for radionuclide j in soil at the beginning of the current annual exposure period per initial unit concentration of parent radionuclide I in soil at time of site release (pCi/g per pCi/g)
C_{si}	=	concentration of parent radionuclide I in soil at time of site release (pCi/g dry-weight soil)

[3]A Quattro workbook containing adjusted parameter sets and all calculations is attached. Names of workbook pages containing calculations associated with adjustments to the external exposure pathway have a standard format consisting of the radionuclide name followed by "ext fix". For example, the page associated with Cobalt-60 is named "Co ext fix".

[4]Equation 5.69, NUREG/CR-5512, Volume 1

SFI = shielding factor by which external dose rate is reduced during periods of indoor residence (dimension less)

SFO = shielding factor by which external dose rate is reduced during periods of outdoor residence and gardening (dimension less)

J_i = number of explicit members of the decay chain for parent radionuclide I

$S\{A_{stj},t_{tr}\}$ = time-integral operator used to develop the concentration time integral of radionuclide j for exposure over a 1-year period per unit initial concentration of parent radionuclide I in soil (pCi•d/g per pCi/g dry-weight soil)

$S\{A_{stj},t_{tg}\}$ = time-integral operator used to develop the concentration time integral of radionuclide j for exposure outdoors over one gardening season during 1-year period per unit initial concentration of parent radionuclide I in soil (pCi•d/g per pCi/g dry-weight soil)

t_g = time during the gardening period that the individual spends outdoors gardening (d for a year of residential scenario)

t_i = time in the 1-year exposure period that the individual spends indoors (d for a year of residential scenario)

t_x = time in the 1-year exposure period that the individual spends outdoors, other than gardening (d for a year of residential scenario)

t_{tg} = total time in the gardening period (d)

t_{tr} = total time in the residential exposure period (d)

24 = unit conversion factor (h/d).

The concentration time-integral factors, S{}, are evaluated for all radionuclides in a decay chain. The factors represent the time integral of concentration during the exposure period of interest.

The concentration factor, A_{stj}, defines the concentration of each radionuclide in soil in a decay chain at the beginning of the current year of the dose evaluation. The concentration includes material initially present in the soil, plus material that has migrated to ground water and been redeposited onto the farmland soil by irrigation with the contaminated water during the previous year.

Equation 2 can be reorganized and simplified to isolate the times and shielding factors of interest:

$$DEXR_i = K \times [(t_i \times SFI) + (t_x \times SFO) + (t_g \times SFO)] \qquad (3)$$

Where

K = combined L1 parameters

and other variables are as defined above.

Assuming that the receptor has an equal probability of being at any point on the site, the time of exposure to the contaminated area can be calculated by multiplying the default exposure time by the ratio of the size of the contaminated area to the Level 1 (L1) default area size. The external dose due to exposure to a contaminated area of any size is calculated by applying the times and shielding factors associated with the area of interest.

The shielding factors are not adjusted in the same way as time of exposure for area of contamination. They are only used to turn the indoor or outdoor external exposure pathway completely on or off. When the pathway needs to be turned off, the shielding factor is set to zero. If the pathway is on, the shielding factor is set to the L1 level. Therefore, the time of exposure is the primary way that the external exposure is varied to account for the size of the contaminated area. The revised external dose is calculated by multiplying K, which is composed of known L1 values, by the modified exposure times and shielding factors:

$$DEXR_i(A) = K \times [(t_i(A) \times SFI) + (t_x(A) \times SFO) + (t_g(A) \times SFO)] \qquad (4)$$

Where

A = contaminated area (m^2),
$DEXR_i$(A) = external dose based on area A from 1 year of residential scenario exposure to radionuclide I in soils (mrem for a year of residential scenario)

and other variables are as described above.

Once the revised external dose has been calculated, the area-corrected DCF, $DCF_{(A)}$, can be calculated. $DCF_{(A)}$ is calculated by first running DandD with parameters (except time) adjusted for the contaminated area of interest. The resulting $DCF_{(X)}$ (DCF without time of exposure modification) is then adjusted by first subtracting the external dose contribution calculated without accounting for the time factor, then adding the corrected external dose:

$$DCF_{(A)} = [DCF_{(X)} - DEXRi] + DEXRi(A) \qquad (5)$$

The area factor can then be calculated by dividing the baseline $DCF_{(L1)}$ by the area corrected $DCF_{(A)}$ for the specific contaminated area of interest.

B) Building Occupancy Scenario

Calculation of external exposure for the building occupancy scenario is simpler than the residential scenario because all exposure occurs inside the building and no shielding factors are used. However, the same need exists to separate the time of exposure to external sources from inhalation and ingestion. Therefore, the external dose is modified after the model is run, in the same general way as described above, and the area-corrected DCF is calculated as shown in equation 5.

1.2 Parameter Specific Assumptions

Most parameters in both the residential and building occupancy scenarios are modified by being multiplied by the ratio of the contaminated area of interest to the L1 default contaminated area. This provides a reasonable and repeatable method for adjusting the impact of various pathways, based on the assumption that such a ratio can act as a reasonable surrogate for variations in the contaminated fraction based on area.

An example of the application of the ratio of contaminated area to L1 default area is demonstrated with the air dust loading factors. These factors are described in NUREG/CR-5512, Volume 1, pages 6.10 through 6.12. The use of dust loading rather than resuspension was originally selected because it was assumed to be the most straight-forward approach for prospective screening, and would require the least number of assumptions regarding input parameters. The base assumption is that the dust loading parameter represents contaminated, respirable dust. Unfortunately, dust loading does not allow direct incorporation of the impact of contaminated area size on the contaminated fraction of resuspended dust. However, a crude approximation of the impact of area can be incorporated by assuming that as the contaminated area decreases in size, the amount of contaminated material versus clean material available for resuspension also decreases. Therefore, while the total amount of dust in the breathing zone would remain the same, the fraction contributed by contaminated soil could be assumed to decrease in direct proportion to the contaminated area. This is approximated by modifying the dust loading parameters by the ratio of contaminated area to the L1 default area.

The resuspension factor, used in the building occupancy scenario, is difficult to adjust because it is insensitive to the distribution of contamination and the size of the contaminated area. As a first approximation, and within the constraints of this study, it is assumed that the resuspension factor can vary between the minimum value assumed in the parameter analysis (1E-6 m^{-1}), and a maximum of the L1 default for areas equal to or greater than the assumed default room size. Analogous to the discussion of dust loading, this approach is based on the assumption that while the resuspension factor may remain constant, the contaminated fraction of material that is resuspended decreases with a reduction in the size of the contaminated area.

For the house scenario, the ratio is modified by the area (186 m^2) that is assumed to be under the house, and which therefore does not contribute to any pathway except external exposure. The fish ingestion parameter is only used to turn aquatic food ingestion on or off, as is the contaminated water ingestion pathway.

Shielding factors are set to either the L1 default value or zero, since they are only used to turn the external exposure pathway on or off. For example, when no contamination is located under the house, the indoor shielding factor is set to zero, and when all contamination is located under the house, the outdoor shielding factor is set to zero.

In most cases, the L1 default parameter value is assumed to be the maximum reasonable value, and areas larger than the default do not cause the parameter value to increase. Since the default is set at a known conservative value, it is not necessary and would likely be unduly unrealistic to assume higher values. Exceptions are the fraction of the diet from the on-site garden, which can increase to a maximum of 0.5, and the time spent gardening, which is tied to garden size.

Appendix E Examples

1. Example applications

A logical, consistent decision process is viewed as a useful tool that will support licensee planning of decommissioning activities and NRC review of license termination requests. To support this process, Chapter 2 of this NUREG describes a decision framework to support implementation of the dose criteria of Subpart E of 10 CFR 20. Three example applications are described in this Appendix which illustrate the cases described in Chapters 3, 4, and 5 of this NUREG.

2.1 Case 1 - Use of the Framework for licensees who use Generic screening

<u>Step 1 Assimilating existing data and information</u>

In checking records to determine the types and amounts of radioactive material they possessed on their site, and gathering information about any surveys and leak tests that had been performed, the licensee in this example determines that:

a) all waste has been properly disposed,

b) sources have been properly transferred to another licensee,

c) minor amounts of contamination have been detected inside a laboratory building during routine surveys.

<u>Step 2 - Scenario Definition/pathway identification</u>

The licensee would note that:

a) The building occupancy scenario applies, with the associated inhalation, secondary ingestion, and external exposure pathways (building occupancy applies to situations where contamination exists on interior building surfaces (but not in the soil) and where the building will be re-used for commercial (not residential) purposes following license termination.

b) for the simple case considered here, Step 2 has already been completed by the NRC, based on the generic scenarios and pathways for screening that have been defined and described in NUREG/CR-5512, Volume 1.

<u>Step 3 - System Conceptualization</u>

For the simple case considered here, Step 3 (conceptual and mathematical model development and assessment of parameter uncertainty) has already been completed by NRC, using the models described in NUREG/CR-5512, Volume 1, by its preparation of the DandD software and the generic screening tables of Appendix A and B.

<u>Step 4 - Dose Assessment</u>

In this example, the licensee could either:

a) run DandD and plug in the maximum surface contamination concentrations from the existing building surveys

b) compare the maximum surface contamination concentrations from the existing building surveys to the generic screening concentrations in Tables A-1 or A-2 of Appendix A.

The maximum survey results should be used because, if the dose assessment using these values indicates that the dose is below the 25 mrem/y criterion, there will be a high assurance that the site meets the dose requirements and additional refinement of the source term will be unnecessary.

<u>Step 5 - Determining if Site can be released</u>

Based on Step 4, the licensee can then simply answer the question of whether the dose assessment results from the model are less than the dose criterion of 25 mrem/y in 10 CFR 20, Subpart E.

In this example, the model results are much less than the 25 mrem criterion.

<u>Step 6 - ALARA requirements</u>

In Step 6 the licensee would satisfy any remaining ALARA requirements (see Reg Guide xxx, Section 3).

<u>Step 7 - License Termination and Site Release</u>

The licensee would:

a) complete paperwork requirements, including documenting the survey results used to calculate the source term and the model output,

b) submit necessary forms and request to have their license terminated by the NRC.

2.2 Case 2 - Licensees who use site specific information but only modify site parameters

This example illustrates use of the framework for a licensee that uses site specific information in their dose assessment. As described Section 2.2, there are a wide range of options for using site specific data ranging from modifying parameters, to modifying models, to remediating the site, to restricting site use.

This example describes use of the framework specifically for those licensees that conclude that the option of modifying parameters will provide a simple, cost effective means to comply with the dose criteria of Subpart E with only limited consideration of other options. This example is prepared separately from Case 3 (which includes a more in-depth evaluation of options) because it is thought that a number of licensees will have relatively low levels and patterns of contamination and will seek to perform a dose assessment by changing certain parameters to more adequately represent their site. This example is not intended to limit the options a licensee may pursue.

In this example, the licensee is interested in terminating the license for an outdoor location that is believed to have areas of soil contamination from leaks in a waste tank.

Although this licensee has a more complex situation than that described in Case 1, they would still follow the same processes in Steps 1 - 5 described for Case 1, at least for the first iteration.

Step 1 - Assimilate Existing Date and Existing Data and Information

The licensee would gather as much information as possible about their site. This might include:

a) radionuclides and processes used,

b) quantities and forms of material that might still remain on site,

c) other information (e.g.,) useful for performing a site dose assessment.

Step 2 - Scenario definition and pathway identification

In this example:

a) because some small amount of soil contamination exists, the residential farmer scenario applies, with the associated inhalation, ingestion, and external exposure pathways (the residential farming scenario applies to situations where contamination exists on soil surfaces to a depth of less than 15 cm with potential for use of the land for residential purposes following license termination).

b) The licensee decides to begin the decision process by using the pre-defined scenarios and pathways in the residential scenario (soil contamination) described in NUREG/CR-5512, Volume 1. As for Case 1, for the simple case considered here, Step 2 has already been completed by the NRC, based on the generic scenarios and pathways for screening that have been defined and described in NUREG/CR-5512, Volume 1.

Step 3 - System Conceptualization

The licensee continues the process of using the pre-defined methods by using the default parameters and the DandD software. For the simple case considered here, Step 3 has already been completed by NRC, using the models described in NUREG/CR-5512, Volume 1, by its preparation of the DandD software and the generic screening tables of Appendix A and B.

Step 4 dose assessment,

The licensee runs DandD using a source term developed from the information gathered in step one, and which is the maximum reasonable value they believe they can defend.

Step 5 - Can site be released

Based on the results of the dose assessment in Step 4, it is clear that the site does not meet the Subpart E dose criterion of 25 mrem/y.

The licensee would therefore proceed to Step 8.

Step 8 - Define Options for Site

There are three options that the licensee could apply either alone or in combination:

a) Option 1 - Activities that reduce uncertainty (information/data collection),

b) Option 2 - Activities that reduce contamination (remediation), and

c) Option 3 - Activities that reduce exposure (land-use restrictions).

Table 2.2.1 lists some of the options that a license could consider, the first two related to Option 1, and the next two related to Options 2 and 3, respectively. In this example, the nature of the soil contamination is relatively simple, and the options are relatively straightforward. In this case the licensee conducts the following fairly simple thought process regarding the options ibn Table 2.2.1:

a) The 1st item in the table would reduce uncertainty in the source term (Option 1) and would require additional site characterization;

b) The 2nd item would replace the default kd with a more site specific value based on the site soil type (Option 1) and would require collection of some additional data;

c) The 3rd option in the table would result in an actual reduction of the quantity of residual radioactivity remaining on the site by use of soil removal activities such as excavating, transporting, and disposing of the soil at a licensed burial site (Option 2).

d) The 4th item in the table, reduction of exposure by restricting use, would require the licensee (per 10 CFR 20.1403) to demonstrate that unrestricted release was not ALARA and to convene an SSAB. This would require additional site specific modeling to ensure that the decision has a sufficient basis (Option 3).

Based on the review, the licensee the licensee chooses Option 1 (and specifically b above), and considers the following in determining what type of information to collect:

a) Reviews the parameter distributions and their rationale as presented in Appendix A.1.2;

b) Considers how to modify the parameters to consider site specific information and determine the data needs to modify the parameters. This would involve review of Appendix A.1.2 which provides information regarding the valid ranges for site specific parameter changes that a license could propose without an additional uncertainty analysis and for which the licensee would need little supporting information to defend changes. This is important in evaluating the relative worth of collecting additional data on these parameters under Step 9 of the decision framework.

Table 2.2.1 - Example Options Definition Table

Expectation	Effect on Dose	Action
Source is believed to be lower concentration than currently modeled	Simulated dose expected to decrease as concentrations decrease	Collect field data to better characterize source distribution
Soil type is expected to be predominantly clay and consequently have higher Kds	Simulated dose expected to decrease as availability of radionuclides to the receptor is decreased	Collect literature and soil map data to defend alternative soil type/texture
Enough soil is expected to be permanently removed to decrease source concentrations so dose level is acceptable	Actual available mass of contaminant decreases, hence simulated dose would decrease	Remediation by soil removal
Controls are expected to remain in place for the duration of the compliance period (if controls fail, simulated doses are between 25 mrem and 100 mrem)	Restrictions will limit uses for site while controls are in place to limit exposure time and pathways to individual; simulated dose will decrease	Set land use restrictions and apply for restricted release

Step 9 - Analysis of Options

To evaluate the likelihood of success, an analysis of the potential outcome (consequence analysis) will need to be performed for each of the options. Depending on the option, this consequence analysis could be very simple (e.g., the option is complete remediation and the consequence is effectively restoring the system to an acceptable condition) to as complicated as refining and expanding the dose assessment. The cost and time necessary to complete each option would also need to be estimated. The consequence analysis should also address the uncertainty associated with each potential outcome. The desired endpoint is a determination of the likelihood or probability that employing a given option will result in meeting the criteria of 10 CFR 20, Subpart E.

The result of the activities performed under Step 9 is a logically organized list of options, and the corresponding cost, likelihood of site release (probability of success), and other important considerations given that the option is pursued. Table 2.2.2 contains examples of how the options could be organized. In some cases, the decision regarding the preferred option will be obvious; for example, a low cost of success and failure, high probability of success option will always be selected over a high cost, low probability of success option. However, the preferred option will not always be obvious, and additional analysis may be needed for sites attempting to balance complex issues.

Table 2.2.2 - Example Options Analysis Table

Alternative Action	Cost (if successful)	Cost (if unsuccessful)	Probability of Success	Required Outcome*
Collect field data to better characterize source distribution	$$	$$	medium	dose less than 25 mrem
Collect literature data to defend alternative soil type/texture	$	$	medium	dose less than 25 mrem
Remediation by soil removal	$$$	$$$	high	dose less than 25 mrem
Set land use restrictions and apply for restricted release				dose w/ controls less than 25 mrem; dose w/o controls less than 100 mrem

*These assume each option is performed in isolation. If performed in combination with other options, each option on its own would not need to achieve a dose less than 25 mrem

To analyze the potential outcome of the selected options, the licensee can use the DandD software to perform some low cost ?what-if" calculations. For example, they can review the existing information about their source term and try to estimate how it would change based on additional characterization. Based on the quality of the existing information, they may be able to modify the source term and obtain a less bounding value. This modified source term would then be input into the model and a revised dose estimate calculated.

In the same way, the licensee could review site specific or regional data to determine the predominant soil type at their site. If the soil type is not well characterized by a clean sand, as was used to define the default soil parameters, the licensee could investigate the impact of changing parameters associated with soil type, such as kd. This process can be continued for other model parameters that the licensee believes could be changed based on site-specific information. This is similar to performing an informal sensitivity analysis, and will help focus attention to those parameters likely to have the most impact on the calculation of dose. The licensee can then direct resources to reducing the uncertainty in those parameters, or can determine that a different approach is necessary before any higher cost activities, such as soil removal or site surveys, are begun.

For this example case, it is assumed that a preliminary evaluation of the remediation option indicates that it is not cost effective to remove the contaminated soil and transport it off site. However, the preliminary analysis is based on the default dose screening and initial bounding estimate of the source term, both of which impact the estimated soil volume requiring remediation, and the cost of remediation. These estimates will change as more site-specific data is obtained, which may make remediation a more reasonable option at another point in the decision process. At this point in the decision process, the idea is not to permanently eliminate options from further consideration, but rather to select the optimum approach for the current state of knowledge.

This step in the decision framework should support an evaluation of the cost and time impacts of both success and failure. Generally, low cost / high likelihood of success options, or combinations of options, are preferred. This step should also include ALARA considerations, in terms of cost/benefit calculations as well as qualitative considerations. With regard to costs, the licensee should consider that if the option(s) selected are successful, the license will be released and further costs will be minimized. However, if the selected option(s) are unsuccessful, it may be necessary to perform additional characterization or remediation, or there may need to be an evaluation of restricted use (with its associated costs).

<u>Step 10 - Select Preferred Option</u>

Based on the DandD analysis and cost estimates for this example, the licensee decides choose Option 1 and specifically to:

a) perform additional characterization of the source term, with the expectation that this will result in the source term estimate being reduced.

b) use the additional characterization that will also involve obtaining data on the site soil type to support revision of the default kd.

The combination of these two actions should have a medium cost and a high likelihood of success.

<u>Step 11 - Implement preferred option</u>

The licensee:

a) develops a characterization plan that will support both radiological and soil data requirements,

b) obtains regional soil maps

c) performs a radiological site survey. If the licensee has a very high expectation that the additional information will be sufficient to support a revised dose assessment that is less than or equal to 25 mrem, it may be worthwhile to design the site survey so that it can be used as a final site survey. However, it is important to note that the final site survey has more extensive requirements than may be needed if the site requires remediation. The extra cost of a final site survey should be weighed against the need to repeat the survey at a later time.

Step 12 - Revise Model Assumptions:

In this example, the licensee revises the parameter values associated with soil type (kd) and source term are modified based on the site data. To support the future request for license termination, the site survey results, soil maps, and methods used to revise Kd are carefully documented.

Reiteration of Step 4 - Iteration 2 Dose Assessment

The revised source term and parameter values are used in iteration 2 of the dose assessment in step 4. In this example, the licensee decides to leave the original default model assumptions and pathways unchanged, and continues to use the DandD software.

In this example, when the revised parameter values are input into the model, the result is a dose less equal to 25 mrem/y.

Reiteration of Step 5

Since the dose assessment result is equal to 25 mrem/y, and the site survey met the minimum requirements for a final release survey, the site can be released.

Step 6 - ALARA

the licensee can move on to consider any remaining ALARA requirements. The licensee can document that best practice procedures were applied as part of its operational program. In addition, ALARA was incorporated and documented in the options definition (step 8), analysis of options (step 9), and selection of the preferred option (step 10).

Step 7 - Release of Site

Based on the above, the license can be terminated and the site released. The licensee submits all required forms, including NRC Form 314, and documentation of the decision process, and the site is released for unrestricted use.

Case 3: Uranium Contaminated Soil

This example will demonstrate the use of the decision methodology and to evaluate compliance with the 25 mrem/y dose criterion for a site with residual soil contamination consisting of depleted uranium. The fictitious site, for the purposes of this example, has been placed in south-central Pennsylvania, in an area that is used for both industrial and agricultural purposes, to support a demonstration of how regional and site-specific data can be used to support parameter changes within the dose model. The following steps refer to Figure 1.

Step 1

The licensee in this example had processed uranium metals for many years, and several outdoor locations are contaminated from that processing. Although this licensee faces a more complex situation than that described in Cases 1 and 2, they would still follow the same steps described above, at least for the first iteration. As before in step one, they would gather as much existing information as possible about their site, including radionuclides and processes used, quantities and forms of material that might still remain on site, and anything else that would be useful for performing a site dose assessment.

Based on the information gathered in step one, the licensee determines that although uranium of various isotopic ratios had been used over several years, operational and special purpose surveys have generally indicated that the contaminant in soil is depleted uranium, and is well characterized by the following activity percentages: 90% U^{238}, 9% U^{234}, and 1% U^{235}. For this example, the licensee is evaluating two widely separated soil contamination areas. The areas are evaluated separately because they are sufficiently far apart that it is reasonable to assume that separate receptors will be involved. One area, (area A), is directly adjacent to an existing storage area, and the other, (area B), is a large open area that had contained a large structure. The structure was demolished and removed several years ago. Area A is approximately 10 m^2, and contains a localized area of highly elevated residual radioactivity; area B is 10,000 m^2 with contamination expected to be relatively uniform and primarily in the top few inches.

Step 2

For the scenario definition and pathway identification in step two, the licensee in this example decides to begin the decision process by using the pre-defined scenarios and pathways in the residential scenario (soil contamination) described in NUREG/CR-5512, Volume 1.

Step 3

In step three, the licensee decides to use the existing default parameters for the NUREG/CR-5512 models and to perform the analysis using the DandD software.

Step 4

For step four, the dose assessment, the licensee runs DandD using the source term developed from the information gathered in step one. This source term represents a defensible maximum value given the existing data sources. The result of the initial dose assessment is as follows: Area A, 20 pCi/g DU, 127 mrem/y; Area B, 9.5 pCi/g DU, 60.5 mrem/y.

Step 5 / Step 8

Based on the results of step four, in step five it is clear that, given only the existing data and NRC default parameters and models, the site has not yet demonstrated compliance with the Subpart E dose criterion of 25 mrem/y for either area A or B. The licensee therefore proceeds to step eight and begins defining options for meeting the 10 CFR Part 20 requirements for license termination. Note that there are basically three options that the licensee can apply either alone or in combination: Option 1 - Activities that reduce uncertainty (information/data collection), Option 2 - Activities that reduce contamination (remediation), and Option 3 - Activities that reduce exposure (land-use restrictions). Table 3.1 lists some of the options that a license could consider, including three related to reduction of uncertainty, one related to reducing contamination, and one related to reducing exposure.

As mentioned in the Case 2 discussion, when evaluating activities that reduce uncertainty under Option 1, it is useful to begin by looking at the default parameter values and dose conversion factor datasets used in the NUREG/CR-5512 model and what they represent. The default parameter values for the NUREG/CR-5512 modeling (that have been implemented in DandD) were developed based on probability distributions representing the expected variability across the country. A probabilistic parameter analysis was performed to develop default radionuclide-specific concentrations and which also provided information regarding the valid ranges for site specific parameter changes that a license could propose without an additional uncertainty analysis. Therefore, the licensee needs minimal supporting information to defend changes to the parameter values that are within the limits specified in the parameter analysis. This is important in evaluating the relative worth of collecting additional data on these parameters under Step 9 of the decision framework.

For example, in evaluating the default parameter values the licensee could look at parameters which impact the water pathway, and which can easily be modified based on site-specific information. For this example, the water pathway parameters listed below were changed since easily-obtainable site-specific information was available. [Note that, as discussed in Appendix E, these parameters should be modified as a group to avoid introducing inconsistencies into the model.] The associated cost for this activity could, for example, be the cost of accessing USGS and state-sponsored sites on the Internet, or the cost of obtaining copies directly from those agencies or the library. This approach of moving away from the reasonably conservative values used in the NUREG/CR-5512 modeling based on site-specific information could be used by all sites until the point that further reduction in simulated dose would require model changes. At that point, probability distributions for the new model parameters may have to be developed and defended by the licensee.

For example, in evaluating the default dose conversion factor datasets the licensee could investigate the values for uranium and associated chain radionuclides that are used in the model. The dose conversion data set in the model is taken directly from Federal Guidance Report 11, and is based on International Commission on Radiological Protection (ICRP) Report 30. In 1994, the ICRP published report 68, which incorporates updated dosimetric information and modeling that resulted in significant changes to the dose factors for uranium and its associated chain radionuclides. While most licensees should use the ICRP 30 values during operations to avoid conflicts with current reporting requirements under 10 CFR Part 20, licensees engaged in decommissioning activities may wish to propose the use of more recent dosimetric information and models to support the best technically defensible approach for estimating the dose from residual radioactivity. Such proposals would not conflict with current reporting requirements for operational facilities. The model output can be adjusted using the updated ingestion and inhalation (1 µm AMAD) CEDE factors in ICRP 68, based on the Table B.1 values to match as closely as possible the assumptions used in 10 CFR Part 20 (i.e. adult male workers).

Model Parameters That Will be Modified Using Site-Specific Information

$\underline{H_2}$: <u>Thickness of the unsaturated zone</u>
The thickness of the unsaturated zone is used in determining radionuclide leach rates from the unsaturated zone to the saturated zone. The default distribution was developed from area-weighted data from observation wells across the U.S. Information on H_2 (also called water table depth) is readily available from state or city governments and the USGS. Data for this parameter are easily available, and licensees using deterministic modeling should use the minimum value (thinnest unsaturated zone) applicable to their site.

$\underline{U_f}$: <u>Ingestion rate for fish from an on-site pond</u>
If the site does not currently support a pond or surface water source (that is or could be impacted by residual contamination from the site during the 1000 year analysis period) that contains edible fish, this parameter should be set to zero. This is equivalent to setting the pond volume to zero. (Note that, in this case, setting this parameter to zero directly eliminates the aquatic pathway.) If a pond does exist at the site, this parameter should be left at the default value.

$\underline{I, f_1, f_2}$: <u>Infiltration rate & saturation ratios</u>
Infiltration rate is defined as the volume of water per unit area per unit time that percolates deeply beneath the root zone and becomes infiltration. The saturation ratio is the volume of water relative to the volume of the pore space, and also the ratio of the moisture content to the porosity. Both these parameters will vary based on regional climate characteristics and site soil texture. A full discussion of these parameters and their derivation, as well as possible information sources for site-specific values, is contained in the attached parameter definitions. Because data are easily available, and because it is not possible, *a priori*, to determine whether high or low values are more conservative, licensees using deterministic modeling should use the best estimate of the median value for their site.

<u>IR: Irrigation water application rate</u>
This parameter represents the annual average quantity of groundwater used to irrigate on site agricultural products. It is used, along with the area of land cultivated (A_r) to calculate the volume of water removed from the aquifer per year for irrigation. Licensees may propose changes to this parameter based on regional precipitation and regional soil moisture levels and other soil properties, and data that support alternative irrigation rates for certain forage crops or edible foods that may be supported due to prevailing dietary patterns or land use patterns. Because it is not possible, *a priori*, to determine whether high or low values are more conservative, licensees using deterministic modeling should use the best estimate of the median value for their site, based on a multi-year state-specific annual average irrigation rate

$\underline{n_1, n_2, D_1, D_2, P_s}$: <u>Porosities, soil bulk densities, and soil areal density of the surface plow layer</u>
Porosity is a measure of the relative pore volume in the soil and is the ratio of the volume of the voids to the total volume. Soil bulk density relates the mass of dried soil to its total volume (solids and pores together). Soil areal density of the surface plow layer is a measure of the mass of soil per square meter in the surface layer, with an assumed depth of 15 cm for the DandD model. Porosity varies with soil texture, and distributions based on the 12 Soil Conservation Service textural classifications are listed in the attached parameter descriptions. Bulk density can be defined as functionally related to porosity: Bulk density = (1 - porosity)*2.65. Soil areal

density is calculated as a conversion of units from bulk density plus the 15 cm depth assumption: Areal density = 150*bulk density or Areal density = 397.5*(1 - porosity). Because it is not possible, *a priori*, to determine whether high or low values are more conservative, licensees using deterministic modeling should use the best estimate of the median value for their site, based on the site-specific soil texture.

As stated above, the options that have been identified in this iteration include three related to reduction of uncertainty. One option is related to reduction of the estimated source term, one is related to reduction of the modeled exposure through use of site-specific parameter values, and one would update the dose conversion factors. The fourth option listed in Table 3.3 would result in an actual reduction of the quantity of residual radioactivity remaining on the site. If the final option, reduction of exposure through restricted release, were pursued, the licensee would be required by 10 CFR 20, Subpart E, to demonstrate that unrestricted release was not ALARA. This would require additional site specific modeling to ensure that the decision had a sufficient basis.

Table 3.3 - Options Definition Table

Expectation	**Effect on Dose**	**Action**
Source is believed to be a lower concentration than currently modeled	Simulated dose expected to decrease as concentrations decrease	Collect field data to better characterize source distribution
Better estimates of parameter values based on site-specific information will be less restrictive	Simulated dose expected to decrease as availability of radionuclides to the receptor is decreased	Collect literature and soil map data to defend alternative soil parameter values
Updated dosimetry is expected to reduce the estimated dose per unit intake	Simulated dose is expected to decrease based on better characterization of uranium dosimetry	Collect literature values and adjust model output
Enough soil is expected to be permanently removed to decrease source concentrations so dose level is acceptable	Actual available mass of contaminant decreases, hence simulated dose would decrease	Remediation by soil removal
Controls are expected to remain in place for the duration of the compliance period (if controls fail, simulated doses are between 25 mrem and 100 mrem)	Restrictions will limit uses for site while controls are in place to limit exposure time and pathways to individual; simulated dose will decrease	Set land use restrictions and apply for restricted release

<u>Step 9</u>

The licensee now moves to step 9, analysis of options in terms of cost and the likelihood of success. To evaluate the likelihood of success, an analysis of the potential outcome (consequence analysis) will need to be performed for each of the options. Depending on the option, this consequence analysis could be anything from complete remediation, with the consequence being a demonstration of compliance with the 10 CFR 20, Subpart E requirements to refining and expanding the dose assessment. The cost and time required to complete each option should be estimated. The consequence analysis should also address the uncertainty associated with each potential outcome. The desired endpoint is a determination of the likelihood or probability that employing a given option will result in meeting the criteria of 10 CFR 20, Subpart E.

The result of the activities performed under Step 9 is a logically organized list of options, and the corresponding cost, likelihood of site release (probability of success), and other important considerations given that the option is pursued. Table 3.4 contains examples of how the options could be organized. In some cases, the decision regarding the preferred option will be obvious, however, this may not be true for certain situations and additional analysis may be required for sites attempting to balance complex issues.

Table 3.4 - Options Analysis Table

Alternative Action	Cost (if successful)	Cost (if unsuccessful)	Probability of Success	Required Outcome[1]
Collect field data to better characterize source distribution	$$	$$	low (A[2]) medium (B[3])	dose less than 25 mrem
Collect literature data to defend alternative soil type/texture	$	$	low (A) medium (B)	dose less than 25 mrem
Collect literature values and adjust model output	$	$	medium (A) medium (B)	dose less than 25 mrem
Remediation by soil removal	$$$ $$$$	$$$ $$$$	high (A) high (B)	dose less than 25 mrem
Set land use restrictions and apply for restricted release[4]				dose w/ controls less than 25 mrem; dose w/o controls less than 100 mrem

[1] These assume each option is performed in isolation. If performed in combination with other options, each option on its own would not need to achieve a dose less than 25 mrem

[2] Area A

[3] Area B

[4] See discussion under Case 2 for an explanation of this option

To analyze the potential outcome of the selected options, the licensee can use the DandD software to perform some low cost ?what-if” calculations. For example, they can review the existing information about their source term and try to estimate how it is likely to change based on additional characterization. Based on the quality of the existing information, they may be able to modify the source term and obtain a less bounding value. This modified source term would then be input into the model and a revised dose estimate calculated.

In the same way, the licensee could review site specific or regional data to determine the predominant soil type at their site, the depth to groundwater, and average precipitation rates. Using this information, the licensee could investigate the impact of changing parameters affecting water pathways. This process can be continued for other model parameters that the licensee believes could be changed based on site-specific information. This is similar to performing an informal sensitivity analysis, and will help focus attention to those parameters likely to have the most impact on the calculation of dose. The licensee can then direct resources to reducing the uncertainty in those parameters, or can determine that a different approach is necessary before any higher cost activities, such as soil removal or site surveys, are begun.

For this example case, a preliminary evaluation of the remediation option indicates that it is not cost effective to remove the contaminated soil and transport it off site for area B, but is cost effective for area A. This preliminary analysis is based on the initial dose screening and initial bounding estimate of the source term, both of which impact the estimated soil volume requiring remediation, and the cost of remediation. These estimates will change as more site-specific data are obtained, which may make remediation a more reasonable option for area B at another point in the decommissioning process. At this point in the decision process, the idea is not to permanently eliminate options from further consideration, but rather to select the optimum approach for the current state of knowledge.

Step 9 in the decision framework should support an evaluation of the cost and time impacts of both success and failure. Assuming all options meet the regulatory requirements, in general, low cost / high likelihood of success options, or combinations of options, are preferred. This step should also include ALARA considerations, in terms of cost/benefit calculations as well as qualitative considerations. With regard to costs, the licensee should consider that if the option(s) selected are successful, the license will be released and further costs will be minimized. However, if the selected option(s) are unsuccessful, it may be necessary to perform additional characterization or remediation, or there may need to be an evaluation of restricted use (with its associated costs).

<u>Step 10</u>

Once the various options have been evaluated, the preferred option can be selected in step 10. Based on the DandD analysis, quality of the survey data available for area A, and cost estimates, the licensee decides to remediate area A. This involves removal of a relatively small volume of soil that has been well characterized, and is expected to result in the area easily meeting the unrestricted release criterion. The decision to remediate in this case is based primarily on information specific to the licensee's business practices and plans related to the future use of area A. For area B, the licensee decides to perform additional characterization to obtain data on the site soil type to support revision of the parameters associated with soils and groundwater. The dose model results will also be modified by the dose factors obtained from ICRP 68. The combination of these options should have a medium cost and a high likelihood of success. At this stage in the analysis, unrestricted release is preferred, and therefore restricted release not considered further at this time.

<u>Step 11</u>

Under step 11, the preferred option is implemented. The contaminated soil in area A is removed and disposed of off-site. Following the remediation, a final survey is performed and documented, and a revised source term for area A is developed from the survey data. The licensee also develops a characterization plan for area B that supports the soil data requirements, then obtains regional soil maps and other data associated with the site geology and hydrology.

Step 12

Once the preferred option has been implemented, the model assumptions, parameter values, and pathways (as appropriate) are revised in step 12 of the decision process. For this example, the area A source term is revised and the area B parameter values associated with soil and groundwater are modified based on the site data and the revised dose factors are obtained. To support the future request for license termination, the site survey results, soil maps, and methods used to revise Kd and dose factors are carefully documented. Table 3.5 lists the parameters, information sources, and revised model parameter values.

Table 3.5 Revised Parameters and Supporting Information

Symbol	Parameters	Discussion
H_2	Thickness of the unsaturated zone	This example site is located in the lower Susquehanna river basin in Cumberland County near Carlisle, Pennsylvania. General information about the lower Susquehanna river basin was obtained through two web sites supported by the USGS. Information associated with the National Water-Quality Assessment Program was obtained from http://www.rvares.er.usgs.gov/nawqa/ne/lsus/lsus_factsheet.html. Depth to water information was obtained from http://www.pah2o.er.usgs.gov/gw_report/. This site contains monthly information for observation wells in counties within the Susquehanna river basin. Each months data includes the minimum and maximum mean depth to water that has ever been recorded for the entire period that the well has been monitored. For the Cumberland county well, data have been recorded since 1951. As a first approximation, the licensee uses the minimum value that has ever been recorded for this well of 12.39 feet, or 3.78 meters.
U_f	Ingestion rate for fish from an on-site pond	This site does not support a pond, and therefore U_f is set to 0.

Table 3.5 Revised Parameters and Supporting Information		
Symbol	Parameters	Discussion
I, f_1, f_2	Infiltration rate & saturation ratios	A silt loam soil texture was determined to be representative of the top 20 cm of soil in the study area, based on information was obtained from the STATSGO data set. Based on Table 1 in the attached parameter discussion for infiltration rate, the mean saturated hydraulic conductivity (K_{sat})is 9.33E-05 cm/s. This is equivalent to an infiltration fraction of about 6%. Infiltration is estimated as follows: I = AR*IF, where AR is the application rate (precipitation plus irrigation) and IF is infiltration fraction. However, the infiltration rate used in the calculations is the lesser of the calculated rate and the saturated hydraulic conductivity. In this case, the calculated value for I is 3.0 in/y, compared to a K_{sat} of 1.16E3 in/y. Therefore, I is 3.0 in/y.
IR	Irrigation water application rate	Mean annual precipitation ranges from 38 to 44 inches in the lower Susquehanna river basin (with 41 inches used as the best estimate for calculating infiltration). Based on the 1992 Census of Agriculture, the average acre-feet/y of water applied from wells for the Mid-Atlantic water resource area was 0.73. This is equivalent to an irrigation rate of 1.37 acre-feet per acre, or 1.14 $L/m^2/d$. Irrigation information obtained from the 1992 Census of Agriculture was downloaded from http://www.census.gov/ftp/pub/prod/1/agr/92fris/
n_1, n_2, D_1, D_2, P_s	Porosities, soil bulk densities, and soil areal density of the surface plow layer	Porosity was obtained for the study area from the STATSGO data set, and has been set to 0.51. Bulk density = (1 - porosity)*2.65 = 1.30 g/cm^3. Soil areal density = 397.5*(1 - porosity) = 195 kg/m^2.
DCFs for U238, U235, U234	ICRP 68 dose conversion factors	Since 99% of the dose is from ingestion, the TEDE results from the model are modified by the ratio of the ICRP 68 ingestion factor to the ICRP 30 ingestion factor. ICRP 30 and ICRP 68 ingestion factors are as follows (Sv/Bq): U238: 6.88E-8, 4.4E-8 U235: 7.19E-8, 4.6E-8 U234: 7.66E-8, 4.9E-8

Second Iteration, Step 4

The revised source term and parameter values are used in iteration 2 of the dose assessment in step 4. In this example, the licensee decides to leave the original default model assumptions and pathways unchanged, and continues to use the DandD software. [Note that in other more complicated situations a licensee might seek to modify these assumptions and pathways. For example, if the groundwater pathway was more complex than could be handled by DandD, especially if the licensee needed to account for real transport or needed to better characterize the actual aquifer because addressing this would reduce the dose estimate, a more complex groundwater model could be substituted within DandD. A detailed submittal discussing such changes would need to be developed]. When the revised parameter values are input into the model, the result following remediation for area A (for 2 pCi/g) is less than 5 mrem/y, and for area B (for 9.5 pCi/g) the dose is less than 25 mrem/y.

Second Iteration, Step 5 & Step 6

This brings the licensee back to step 5 and the question regarding whether the site can be released. Since the dose assessment result is less than or equal to 25 mrem/y, and the licensee can move on to consider any remaining survey and ALARA requirements. The licensee can document that best practice procedures were applied as part of its operational program. ALARA was incorporated and documented in the options definition (step 8), analysis of options (step 9), and selection of the preferred option (step 10).

Step 7

Based on the above, the license can be terminated and the site released. The licensee submits all required forms, including NRC Form 314, and documentation of the decision process, and the site is released for unrestricted use.